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Cement Kiln Pressure and Temperature Response Based FLC Logic

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Abstract

Control system comprises of controller unit, sensor, transducer, and configuration modules to give a desired response. Relevant review literatures reported appreciable performance of Fuzzy Logic Controller (FLC) as controller unit. Consequently, this work explored FLC based logic controller to control pressure and quantity of the material in a kiln with paramount to temperature control for high quality clinker production. In this process instrumentation, the temperature as a function of the pressure allows a good flaming of the gas for a derivative of good energy balance to function as a high-quality product, the clinker. Pressure and temperature instrumentation were employed via the principle of quantity of material flow and flaming. Pressure of material and temperature of gas at the inlet of the kiln were prioritized to produce clinker in the kiln via FLC logic, which exited at its outlet. Subsequently, the obtained results indicated the response of the kiln temperature increases as the pressure in the kiln increases. Hence, it led to production of a proper baking of the raw mix to produce the clinker. In addition, the increase in the pressure of the internal environment of the kiln was traceable to inflow of the material. Resultantly, as the quantity of material flowing into the kiln increases, the temperature as a function of pressure in the kiln also increases. The FLC based logic controller is applicable to cement kilns control system for a better-baked clinker and reduction in cost of the product.

Keywords: Cement Kiln; Clinker; FLC; Pressure; Quantity of Material; Temperature

Introduction

Control System is a functional combination of different components that contain controller units for modification of input parameters using information relevant to the expected output of the system to produce it (expected output). Error is the control engineering term for the most essential relevant information for the modification action of the controller units. Some researchers had reported and reviewed the use of PID controller and Fuzzy Logic Controller (FLC) in numerous control system applications and solutions in optimising error control (Almukhtar, 2013; Joseph and Fadare, 2024; Kumar et al., 2022; Mahmud and Tao, 2013; Pekh et al., 2023; Phan et al., 2024; Rajaji et al., 2015). Emphatically, the focus on the use various applicable controllers in control based kiln system for efficient clinker production is an appreciable target of

research in control and power electronics engineering (Joseph and Fadare, 2024; Liu et al., 2020; Phan et al., 2024; Yan et al., 2001; Zhang, 2017).

The control of physical parameters like the flow rate, pressure, quantity of material and temperature in a kiln are paramount to high quality clinker production (He et al., 2022; Joseph and Fadare, 2024; Koumboulis and Kouvakas, 2002; Mariani et al., 2016, 2017). This process of clinker production utilizes pressure and temperature process instrumentation via the principle of quantity of material flow and flaming. Pressure and temperature of gas and material are very vital at the inlet of the kiln chamber to produce clinker in the kiln, which exits at its outlet (He et al., 2022). This paper focused on research on the analysis of the effect of quantity of material flow into the kiln and/or the pressure inside the kiln with respect to the baker temperature.

Review of Relevant Literatures

The paramount inference from review of relevant literatures in control system based kiln and furnace is that basic physical control system input parameters are flow rates, pressure and temperature (Aghdasinia et al., 2021; Doghmane et al., 2022; Joseph and Fadare, 2024; Joseph and Olabode, 2022; Liu et al., 2020; Phan et al., 2024; Schachenhofer, 2007; Yan et al., 2001; Zhang, 2017). Joseph and Fadare (2024) observed that a unit step in error indicated a remarkable increasing effect in the kiln response according to their work, which was based on the ideology of error/error change to the determination of the temperature response of the kiln using a PID controller (Joseph and Fadare, 2024). Schachenhofer (2007) developed a measurement assembly, measuring temperature and pressure at several positions simultaneously. In addition to the existing measuring points at the preheater tower, new measuring points for hand-held measurement have been installed. The measurements itself were executed with mobile equipment consisting of a control unit, data loggers, thermocouples and differential pressure probes (Schachenhofer, 2007).

Sauki & Irawan (2015) Based on experiment made, asserted that temperature and pressure do play an important role for the chemical and physical alteration of cement by CO₂ attack. It was observed that cement tends to degrade and loss its strength once exposes to supercritical CO₂ environment. The loss in compressive strength was greater at increase temperature due to the formation of alpha-calcium silicate. For pressure, the loss of compressive strength was greater at increased pressure (Sauki and Irawan, 2010). (Sauki & Irawan, 2015). Gouda et al. (2000) observed that FLC is more efficient and robust in comparison to the PID controller in their comparison experiment using simulated building space and water heating system (Gouda et al., 2000). The advance research work of He et al. (2022) affirmed the efficacy of FLC which enhanced their achievement of Coordinated Optimization Control System of Big Data Intelligent Production Line for Cement Clinker Production Line (He et al., 2022). Similar to requirement of data He et al. (2022), Sutawijaya and Kayi (2021) required previous data for the efficacy of their model for clinker production using Cement Quality Management (CMQ) operating system.

Consequently, this work was an attempt to avoid complexity brought in by CMQ of Sutawijaya and Kayi (2021), hence, FLC was explored to provide the control of basic parameters for clinker production in kiln. In addition, the work was to observed the dynamics of using pressure as part of the physical input parameters and FLC logic controller to affirm the work of other reserachers.

Research Method

FLC comprises of fuzzification, inference mechanism and defuzzification (Joseph and Olabode, 2022). In temperature control by pressure function, the FLC has four vital components as follows:

- i. Fuzzification;

- ii. knowledge base;
- iii. decision-making logic, where the rules are introduced and
- iv. the defuzzification.

In this work, fuzzification involved the transformation of the crisp data is into language format understood by the system. It was the fuzzy inference system for the analysis and assignment of various input parameters with their respective variables. In addition, the Sugeno type inference system approach was applied for performance analysed. At the defuzzification unit, the fuzzy sets was transformed back to real-life data for the plant's use. Figure 1 shows the system configuration.

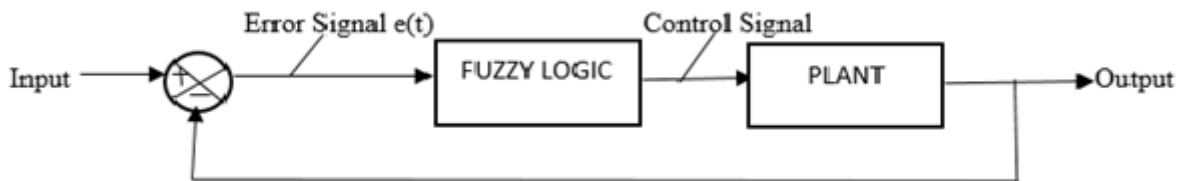


Figure 1: FLC System Configuration

For better analysis of this work, Matlab graphical user interface was adopted for the simulation with second order transfer function for the kiln as represented below:

$$\text{Transfer Function} = \frac{A\omega^2}{s^2 + 2\tau\omega s + \omega^2} \quad (1)$$

Where A = gain, ω = resonant frequency of oscillation in rad/sec,

τ = damping coefficient, which ranges between 0 and 1.

Result and Discussion

The results obtained from the FLC Control System simulation using Matlab in conjunction with the field data are discussed in this section. Figure 2 presents the response of the kiln temperature against the pressure. The tabular analysis of the response is also shown in Table 1. The temperature axis is represented in grade, with the lowest grade of 0.25, while the highest grade is 0.5. For the pressure axis, it is represented in Bar, the lowest being 50 Bar, while the highest being 130 Bar.

Table 1: Response of Kiln Temperature against Pressure

Kiln Temperature (in Grade)	Pressure (Bar)
0.2500	56
0.3625	60
0.4500	65
0.4750	70

0.5000	75
0.5000	80
0.5000	85
0.5000	90
0.5000	95
0.5000	100
0.5000	105
0.5000	110
0.5000	115
0.5000	120
0.5000	125
0.5000	130

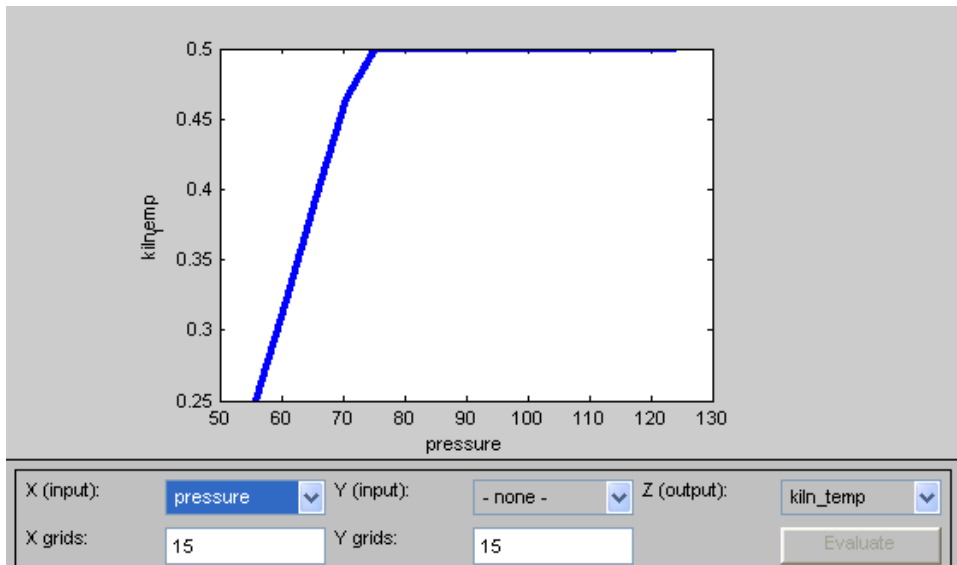


Figure 2: Kiln temperature against pressure

Furthermore, Figure 3 displays the response of the kiln temperature against the quantity of material. The tabular analysis of the response is as shown in Table 2. The temperature axis is represented in grade, with the lowest grade of 0.2, while the highest grade is 1. For the quantity of material axis, it is represented in Kg, the lowest being 3000 Tons, while the highest being 3500 Tons. In addition, Figure 4 shows the three-dimensional

view of the performance of the Sugeno FIS based fuzzy logic controller.

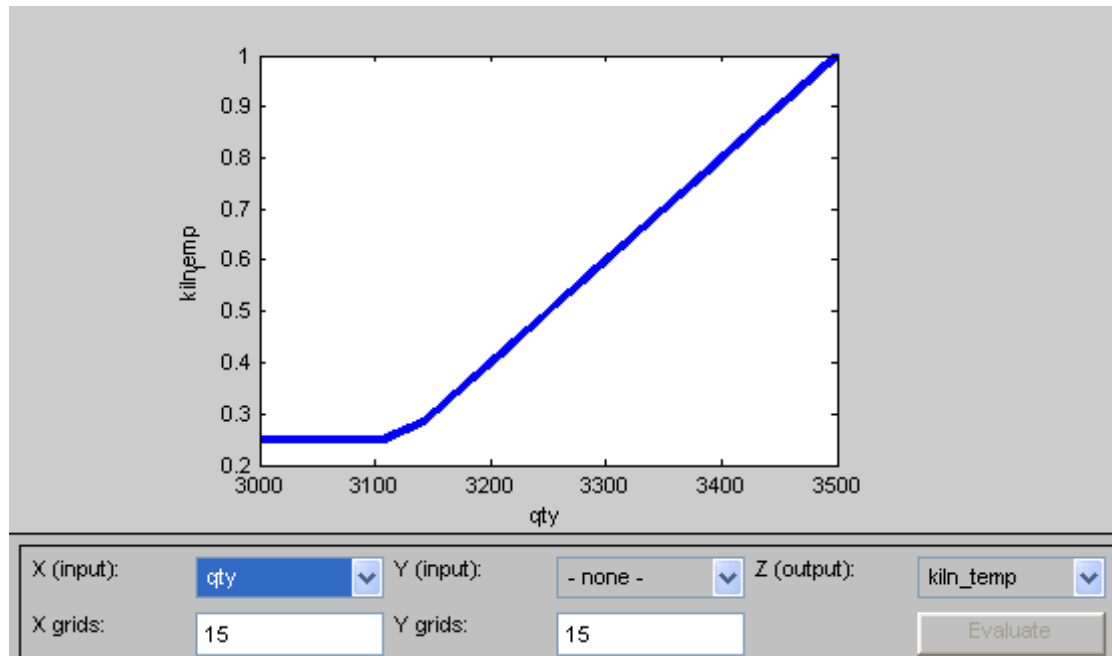


Figure 3: Kiln temperature against clinker quantity

Table 2: Response of Kiln Temperature against Clinker Quantity

Kiln Temperature (in Grade)	Quantity of Materials (Tons)
0.2500	3000
0.2500	3100
0.4000	3200
0.6000	3300
0.8000	3400
1.0000	3500

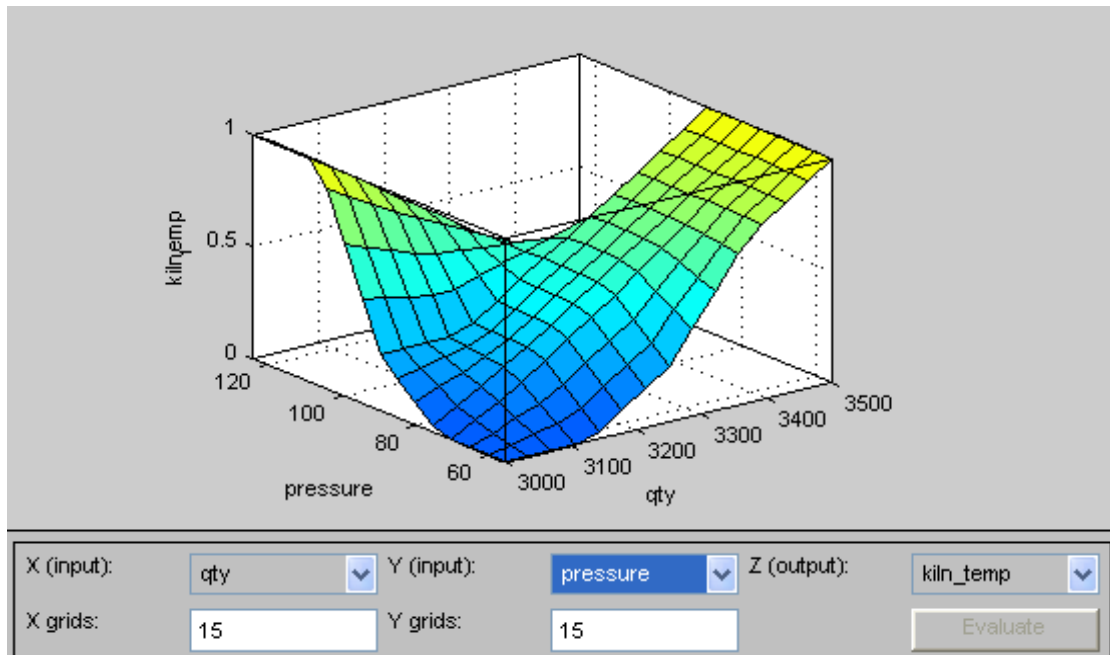


Figure 4: Three dimensional view of Sugeno based fuzzy inference system

Figure 2 and Table 1 inferred that the response of the kiln temperature increases with pressure increase in the kiln. The increase in the pressure of the internal environment of the kiln was due to inflow of the material. Consequently, as the quantity of material flowing into the kiln increases, the pressure in the kiln also increases (as depicted by Figure 3 and Table 2). As the input sensors for field data acquisition sensed the increments in pressure, the FLC controller translated it to an increase in the gas flame and/or temperature.

Therefore, the following submission could be deduced from the analytical discussion above:

- i. It consumes less energy.
- ii. Reduction in the time of finished/end product and hence, reduction in the cost price of end product.

Conclusion

Conclusively, for a better production process, the clinker is obtained due to increased pressure in the kiln chamber due to increase inflow or material. This pressure increment is sensed by the sensor, which translates it into an increase in temperature. By this increase in temperature, the raw material could be better baked to give the final product at reduced energy consumption and reduced period of production. Subsequently, the advantage of relative low cost of production could be achieved due to lower cost of energy and period of production.

Contribution to Knowledge

This research gives the following contributions to knowledge;

1. Product quality of cement is ascertained due to the availability of accurate production parameters;

2. Increase temperature in the kiln chamber leads to lower production time and cost.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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References

- [1] Aghdasinia, H., Hosseini, S. S., and Hamed, J. (2021). Improvement of a cement rotary kiln performance using artificial neural network. *Journal of Ambient Intelligence and Humanized Computing*, 12(7), 7765–7776. <https://doi.org/10.1007/s12652-020-02501-1>
- [2] AlMukhtar, A. H. (2013). Design of phase compensation for solar panel systems for tracking sun. *Energy Procedia*, 36, 9–23. <https://doi.org/10.1016/j.egypro.2013.07.003>
- [3] Doghmane, M. Z., Kidouch, M., Eladj, S., and Ouali, A. (2022). Identification and Modeling of a Rotary Kiln in Cement Plant Based on ANN (MLP). *Lecture Notes in Networks and Systems*, 361 LNNS, 825–836. https://doi.org/10.1007/978-3-030-92038-8_84
- [4] Gouda, M. M., Danaher, S., and Underwood, C. P. (2000). Fuzzy Logic Control Versus Conventional PID Control for Controlling Indoor Temperature of a Building Space. *IFAC Proceedings Volumes*, 33(24), 249–254. [https://doi.org/10.1016/S1474-6670\(17\)36900-8](https://doi.org/10.1016/S1474-6670(17)36900-8)
- [5] He, S., Cao, G., Ma, G., Duan, J., and Bai, J. (2022). Coordinated Optimization Control System of Big Data Intelligent Production Line. *Wireless Communications and Mobile Computing*, 2022(1). <https://doi.org/10.1155/2022/1621445>
- [6] Joseph, E. A., and Fadare, S. A. (2024). Error Effect and Control System Response in PID Controlled Kilns. *International Journal Of Research In Engineering Management And Science (IJPREMS)*, 04(12), 840–843.
- [7] Joseph, E. A., and Olabode, O. R. (2022). Development of Fuzzy Logic Controller Based Temperature Control for Kiln Control. *Iconic Research and Engineering (IRE) Journals*, 6(1), 684–688.
- [8] Koumboulis, F. N., and Kouvakas, N. D. (2002). Indirect adaptive neural control for precalcination in cement plants. *Mathematics and Computers in Simulation*, 60(3–5), 325–334. [https://doi.org/10.1016/S0378-4754\(02\)00024-1](https://doi.org/10.1016/S0378-4754(02)00024-1)
- [9] Kumar, M., Uqaili, M. A., Memon, Z. A., and Das, B. (2022). Experimental Harmonics Analysis of UPS (Uninterrupted Power Supply) System and Mitigation Using Single-Phase Half-Bridge HAPF (Hybrid Active Power Filter) Based on Novel Fuzzy Logic Current Controller (FLCC) for Reference Current Extraction (RCE). *Advances in Fuzzy Systems*, 2022. <https://doi.org/10.1155/2022/5466268>
- [10] Liu, R., Hu, E. D., Zhu, Z., Mao, L., and Ma, Z. (2020). Study on temperature control system of ceramic kiln based on fuzzy PID cascade. *Proceedings of 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference, ITNEC 2020*, 1769–1772. <https://doi.org/10.1109/ITNEC48623.2020.9085049>
- [11] Mahmud, K., and Tao, L. (2013). Vehicle speed control through fuzzy logic. *2013 IEEE Global High Tech Congress on Electronics, GHTCE 2013*, 1, 30–35. <https://doi.org/10.1109/GHTCE.2013.6767235>
- [12] Mariani, F., Risi, F., and Grimaldi, C. N. (2017). Separation efficiency and heat exchange optimization in a cyclone. *Separation and Purification Technology*, 179(February), 393–402. <https://doi.org/10.1016/j.seppur.2017.02.024>
- [13] Mariani, F., Risi, F., and Poggiani, C. (2016). Numerical study of the separation efficiency and heat exchange performance in a complex gas-solid separator. *International Journal of Computational Methods and Experimental Measurements*, 4(2), 142–152. <https://doi.org/10.2495/CMEM-V4-N2-142-152>

- [14] Pekh, P., Khrystynets, N., Gubysh, R., and Shulgach, V. (2023). Simulation of two-stage temperature regulation system. *Computer-Integrated Technologies: Education, Science, Production*, 53. <https://doi.org/10.36910/6775-2524-0560-2023-53-08>
- [15] Phan, V. Du, Nguyen, X. H., Dinh, V. N., Dang, T. S., Le, V. C., Ho, S. P., Ta, H. C., Duong, D. T., and Mai, T. A. (2024). Development of an Adaptive Fuzzy-Neural Controller for Temperature Control in a Brick Tunnel Kiln. *Electronics (Switzerland)*, 13(2). <https://doi.org/10.3390/electronics13020342>
- [16] Rajaji, V. D., John, D. A. D. A., and John, D. A. D. A. (2015). Power Compensation using Fuzzy Logic Based For Grid Interactive PV System. *Ijireeice*, 3(2), 94–100. <https://doi.org/10.17148/ijireeice.2015.3220>
- [17] Sauki, A., and Irawan, S. (2010). Effects of Pressure and Temperature on Well Cement Degradation by Supercritical CO₂. *International Journal of Engineering & Technology IJET-IJENS*, 10(04), 53–61. <http://eprints.utp.edu.my/4729/>
- [18] Schachenhofer, E. (2007). Verification of Pressure and Temperature of a Modern Precalciner System Diploma Thesis Chair of Thermal Processing Technology. June.
- [19] Sutawijaya, A. H., and Kayi, A. (2021). Optimizing the clinker production by using an automation model in raw material feed. *International Journal of Industrial Optimization*, 2(1), 17. <https://doi.org/10.12928/ijio.v2i1.3002>
- [20] Yan, G. C. K., De Silva, C. W., and Wang, X. G. (2001). Experimental modelling and intelligent control of a wood-drying kiln. *International Journal of Adaptive Control and Signal Processing*, 15(8), 787–814. <https://doi.org/10.1002/acs.656>
- [21] Zhang, J. (2017). Research on the design of ceramic kiln control system based on PID. *Chemical Engineering Transactions*, 59, 709–714. <https://doi.org/10.3303/CET1759119>