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Development of Fuzzy Logic Controller for Cement Mill

Stephy Retnam
Electrical and Electronics Dept.
Mar Baselios College of Engg.
Trivandrum, Kerala, India.

Pratheesh H
Senior Engineer
Control & Instrumentation Group, CDAC
Trivandrum, Kerala, India.

Aswin R B
Assistant Professor
Electrical and Electronics Dept.
Mar Baselios College of Engg.
Trivandrum, Kerala, India.

Abstract- In this paper a fuzzy logic controller is used to control a MIMO (Multiple Input Multiple Output) system. Fuzzy logic controller is used for modeling and solving problems which involves imprecise knowledge and mathematical modelling. Fuzzy sets support many degrees of membership between 0 and 1. The control is provided in order to control the flow rate which in turn affects the rest of the process that follows. Plugging is a major issue which causes instability in cement mills. If proper crushing is not performed fineness of cement will be affected. The temperature inside the rotary kiln determines the quality of cement and the physical properties like fineness, soundness etc are achieved during the milling process. Depending on the ability of cement to set in water it can be classified as hydraulic and non-hydraulic. Quality of cement is determined by mortar compressive strength. Chemical structure, fineness and particle size distribution of finished product have a strong influence on mortar compressive strength. A ball mill circuit can be made to work efficiently and stably with the help of fuzzy logic control. Since cement mill have interconnected processing operations the system is complex. Main difficulty of cement ball mill load is large delay time which is solved using sampling control strategy of fuzzy logic control.

Index terms – Fuzzy logic controller, Ball mill

1. INTRODUCTION

Cement is a hydraulic binder which sets and hardens when water is added to it. Its known as a hydraulic binder because it hardens when water is added. Once it is hardened it retains its strength and stability even under water. The word cement can be traced back to the Roman term opus caementicium. This term is used to describe masonary which resembles modern concrete. Cement needs raw materials that include calcium, silicon, iron and aluminum. Basic constituents of cement include limestone and clay. Ability of the cement to set in water varies and depending on that cement can be characterized as hydraulic and non-hydraulic.

Cement is usually gray in colour. White cement is also available, but its very expensive. White cement and gray cement are similar in all aspects except that white cement has a high degree of whiteness. White colour is acquired due to the change in raw materials used. Metal oxides mainly iron and manganese influence the whiteness of the material. It is readily found in North America.

Physical properties of cement include 1.Setting time 2.Soundness 3. Fineness 4. Strength. Care should be taken in case of storage of cement. If it gets dump or wet the fine powder will turn into a hard lump. Therefore it should always be stored in dry area. Quality of cement is determined by mortar compressive strength. Cement is obtained by fine grinding of cement clinker and, gypsum. The clinker is obtained by burning a mixture of limestone and clay in certain percentage in addition to some corrective materials in rotary kilns [1]. Rotary kiln is a pyroprocessing device. A cement mill or finish mill is the equipment used to grind the hard, nodular clinker from the cement kiln into the fine grey powder that is cement.

2. DYNAMIC MODEL OF CEMENT MILL

Consider a steady state operation. Fig.1 shows the ball mill circuit. The cement ball mill circuit should fulfill the rules of indestructibility of matter for steady-state operation [7]. The following equation exists under steady state condition:

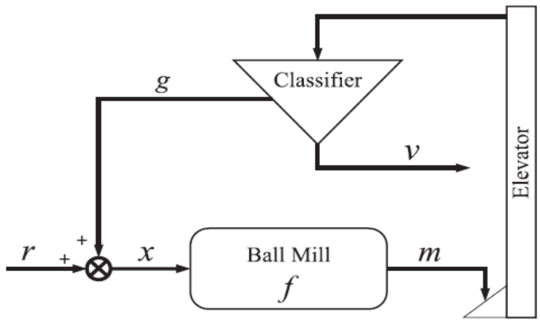

Fig.1: Ball mill circuit

$$m = x \quad (1)$$

The equation (1) can also be written as

$$m = x = r + g = v + g \quad (2)$$

$$r = v. \quad (3)$$

Schematic view of cement mill is shown in Fig.2. U is the feed flow rate in Tons/hr. Yr is the recirculating flow of fine particles in Tons/hr and Yf is the fine product flow in Tons/hr. Z is the ball mill load in Tons. Hardness of material inside the mill is denoted as d. Clinker, gypsum and slag together form the input to the ball mill. The raw

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materials are crushed and grinded and is passed to the separator with the help of an elevator. Separator is used to separate the fine particles and coarse particles.

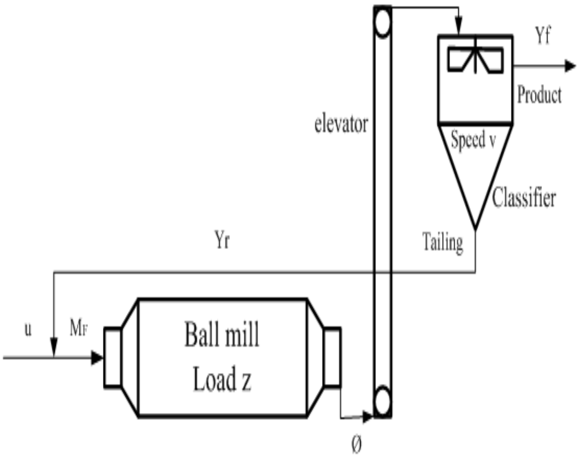

Fig.2 Schematic view of cement mill

Under normal operation:

$$\left.\begin{aligned} T_f\dot{y}_f &= -y_f + (1-\alpha(z,v,d))\varphi(z,d) \\ \dot{z} &= -\varphi(z,d) + u + y_r \\ T_r\dot{y}_r &= -y_r + \alpha(z,v,d)\varphi(z,d) \end{aligned}\right\} \quad (4)$$

$$\alpha = \frac{\Phi^m * v^n}{\Phi^m * v^n + K\alpha} \quad (5)$$

$$K\alpha = (u + Yr)^m * v^n \left[\frac{u+Yr}{Yr} - 1\right] \quad (6)$$

m=0.8; n=0.4; $KØ_1$=0.116; $KØ_2$=16.50

$$Tf=0.3h, \; Tr=0.01h \quad (7)$$

$$\varphi = \max\{0,(-dKØ_1 Z^2 + KØ_2 Z)\} \quad (8)$$

These are the differential equations that describe the model [6].

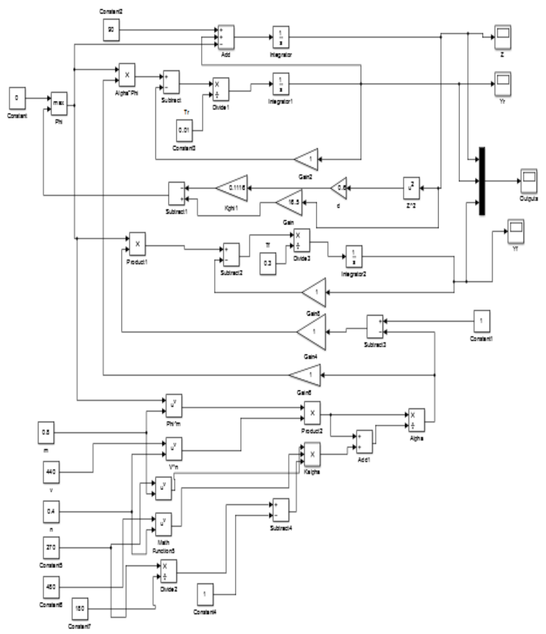

Fig.3 Simulink model of cement mill

The first step involved in cement production is to quarry the raw materials. These raw materials are crushed and fed to a raw mill. Raw mill is also known as secondary crushers or hammer mills. Raw mill output is known as “raw feed” or “kiln feed”. This raw feed must be pre-heated and completely dried up before passing it through the kiln [2].Pre heating is performed to remove the moisture content of raw materials and break-up silicates as well as calcinate partially the present carbonates in the material [5]. Hot gases are formed inside the kiln during the production of clinker and these gases flow in opposite direction to that of raw meal. It is this hot gas that is responsible for pre-heating. After pre-heating it is passed to the rotary kiln.

Calcification is the first action done on the raw mill at the kiln by such high temperature. The high temperature at the burning zone melts the input materials. Then main burning is gradually started and chemical reactions are done between silicates and the present oxygen of the air. CO gas includes the main part of the combustion smokes. [1].

The cylinder rotates around its axis and the raw meal dust sticks adhesively to its walls. There it gradually gets burned and baked to produce clinker [5]. The end part of the rotary kiln is provided with secondary air and coal which produces flame. The temperature obtained at that point should be at a range of 1350°C to 1450°C.The gas so produced passes through the rotary kiln in a counter clockwise direction to that of raw meal and it is this gas that helps in pre-heating.

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The clinker (C_3S) produced is measured in weight/litre. It is then cooled and is allowed to pass through a crusher. Also it is mixed with gypsum and slag or fly ash. Depending upon this combination and variation in temperature different types of cement are produced. The main physical properties of cement are achieved during milling process. The optimum value for fineness is 330m2/kg. Clinker, gypsum and slag are fed to a feeder from a hopper. These three materials are fed in a particular ratio and is known as model set rate. An electronic ear is provided near to cement mill. It acquires all sorts of sounds which occur in metal walls. . Ball mill load can be measured by means of measuring the noise of ball mill [7]. Depending on the sound produced it could be understood that whether the mill is empty or not.

The efficiency of a grinding circuit is dependent on three key conditions [9]:

- An optimum and constant level of material in the mill;
- Constant air to material ratios for the separator material flows:
- A constant and optimum ratio between fresh feed and rejects at the mill inlet.

An Electro Static Precipitator (ESP) is a filtration device that removes fine particles like dust and smoke. Cement mill is connected to this. A fan is connected to ESP and due to this force that is created by fan to draw the dust particles, the cement particles flow to the bucket elevator. From bucket elevator it is passed to a separator. A separator consists of two fans. As the name suggests separator is used for separating the materials into two classes, namely product and tailing. Product is the fine cement particle that is produced according to our requirement and tailing is the oversize material (also known as circulating load [3]) that are fed back to the cement mill for further grinding.

3. FUZZY LOGIC CONTROLLER

Fuzziness means vagueness. Fuzzy set theory is an excellent tool to handle the uncertainty arising due to vagueness. Fuzzy logic control system is better than the PID control system in terms of robustness and less sensitiveness to parameter variations [8].Fuzzy control consists of an input stage, a processing stage and an output stage. In crisp set the values are either full or none that is either 1 or 0. Whereas a fuzzy set supports many degrees of membership between 0 and 1. Fuzzy logic design is not based on the mathematical model of the process. The fuzzy controllers designed using fuzzy logic implements human reasoning that has been programmed into membership functions, fuzzy rules and rule interpretation. The fuzzy logic controller involves four main stages: fuzzification, rule base, inference mechanism and defuzzification. Fig.4 shows the block diagram of FLC.

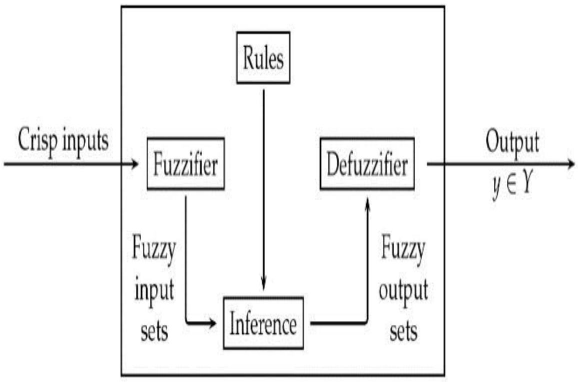

Fig.4: Block diagram of FLC

Fuzzy has been implemented in cement mill with:

a. Two inputs and two outputs
b. Four inputs and two outputs

Two inputs and two outputs - A fuzzy control with 5 membership functions is used here. Error in recirculating flow 'eyr' and error in ball mill load 'ez' is given as input and the output is u (total feed) and v (fan speed). The number of rules that can be written depends upon the number of membership functions and the number of inputs. (No. of membership functions) (No. of inputs) is the formula to obtain the number of rules. Here there are 5 membership functions and 2 inputs. So 25 rules can be written. Negative Big(NB), Negative Small(NS), Zero(Z), Positive Small(PS), Positive Big(PB) are the 5 different MFs in the input side. Low(L), Medium Low(ML), Normal(N), Medium High(MH), High(H) are the 5 different MFs in the output side.

Four inputs and two outputs – Derivative of both errors are also taken here. That is here the inputs are error in recirculating flow 'eyr', error in ball mill load 'ez' derivative of error in recirculating flow 'deyr' and derivative of error in ball mill load 'dez'. $(\text{No.of membership functions})^{(\text{No.of inputs})}$ is the formula to obtain the number of rules. Here there are 5 membership functions and 4 inputs. So 625 rules can be written. Negative Big(NB), Negative Small(NS), Zero(Z), Positive Small(PS), Positive Big(PB) are the 5 different MFs in the input side. Low(L), Medium Low(ML), Normal(N), Medium High(MH), High(H) are the 5 different MFs in the output side.

By adding more number of inputs the output value that is obtained is more fine than the value that is obtained from two input two output system. Fig 5 shows the Simulink model of fuzzy with fuzzy logic controller incorporated in it.

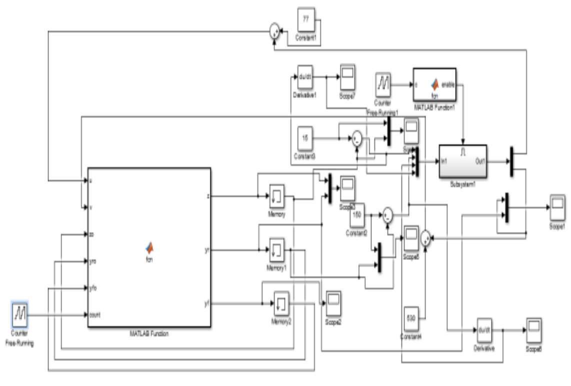

Fig 5 Simulink model with fuzzy

4. SIMULATION RESULT

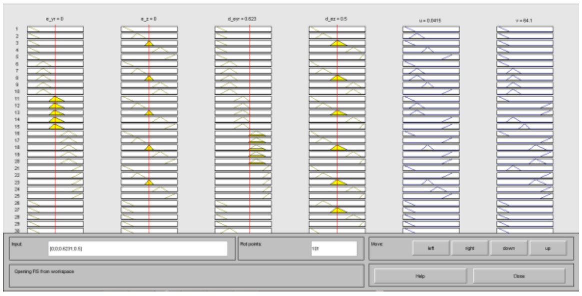

Fig 6: FIS editor- rule base

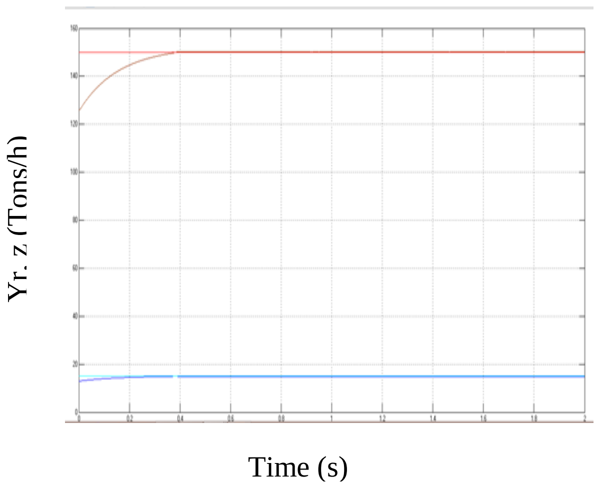

Fig 7: Simulation result for 4 input and 2 output

The system was simulated using MATLAB – SIMULINK. Load mill z and recirculating flow Yr is found to settle at the given set point. Fig.6 shows the simulation result for four inputs and two outputs.

5. CONCLUSION

Modelling of cement mill under steady state condition has been performed and modelling under normal condition has been done. A study on manufacturing of cement was conducted and it was understood that the quality of cement varies with the temperature inside the rotary kiln and the physical properties depends on cement milling. Modelling was conducted and Fuzzy control was introduced in the plant. Based on fuzzy approximation suitable control laws can be developed. Non-linear system dynamics is approximated using fuzzy. Fuzzy logic controller has been implemented for two inputs and four inputs with two outputs. The process was considered to be a nonlinear and time-delay system. The fuzzy logic controller does not need accurate mathematical model of the process. The simulation results were given for different operating conditions and are able to fulfill the control task.

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