GAP DETERMINATION FOR CLINKER PREPARATION KILNS

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Abstract. Cement kilns are the heart of the cement production process; they are used for the pyroprocessing stage of manufacture of Portland and other types of hydraulic cement. Their capacities usually define the capacity of the cement plant. The gaps between the kiln and the rings which support the kiln have to be constant. The gap has to be kept between two limits so that the force of friction is great enough to avoid uncontrolled sliding between the ring and the shell of the kiln. If these are not equal for all of the rings, they can twist the kiln. The measurement of the temperature of the shell and of the kiln, and the computing of the gap based on these two are difficult. The purpose of this work is to build up a measuring system for the gap, based on the measurement of the time of an entire rotation of the two entities using a programmable logic controller (PLC). The computing algorithm has been applied to determine the gap for the clinker kiln at the cement mill LAFARGE Hoghiz. The results obtained have been verified. Before the kiln was turned on, a line a line has been drawn starting on the ring and ending on the shell of the kiln. By measuring the distance between the two lines after the accomplishment of n rotations the gap has been determined manually. This gap was then compared with gap determined by the PLC and the two were nearly equal. The higher the number of rotations taken into account is, the greater the precision of the obtained gap will be. Because the gap is determined by a program, the result can then be sent to higher ranked system which can take a decision which will cause the growth or the decrease of the gap.

Keywords: rotary kiln, furnace, tunnel kiln, cement kiln, cement breaking heater

1. Introduction

Cement kilns are used for the pyroprocessing stage of manufacture of Portland (the most common type of cement in general use around the world) and other types of hydraulic cement, in which calcium carbonate reacts with silica-bearing minerals to form a mixture of calcium silicates. Over a billion tones of cement are made per year, and cement kilns are the heart of this production process: their capacity usually define the capacity of the cement plant. As the main energy-consuming and greenhouse-gas–emitting stage of cement manufacture, improvement of their efficiency has been the central concern of cement manufacturing technology.

The rotary kiln consists of a tube made from steel plate, and lined with firebrick. The tube slopes slightly (1° ÷ 4°) and slowly rotates on its axis at between 30 and 250 revolutions per hour. Rawmix is fed in at the upper end, and the rotation of the kiln causes it gradually to move downhill to the other end of the kiln. At the other end fuel, in the form of gas, oil, or pulverized solid fuel, is blown in through the "burner pipe", producing a large concentric flame in the lower part of the kiln tube. As material moves under the flame, it reaches its peak temperature, before dropping out of the kiln tube into the cooler. Air is drawn first through the cooler and then through the kiln for combustion of the fuel. In the cooler the air is heated by the cooling clinker, so that it may be 400 to 800 °C before it enters the kiln, thus causing intense and rapid combustion of the fuel. Rotary kilns run 24 hours a day, and are typically stopped only for a few days once or twice a year for essential maintenance. This is an important discipline, because heating up and cooling down are long, wasteful and damaging processes.

The clinker preparation kiln is supported by a number of rings; their number depends on the length of the kiln. The shell of the kiln leans on the ring, which in turn slides on two rollers (figure 1).

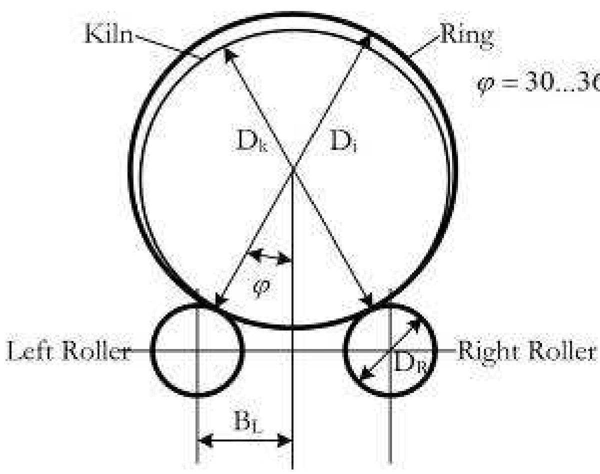

Figure 1. Mechanical structure of a clinker preparation kiln

The driving mechanism is linked to the kiln. The ring is driven by the force of friction between the kiln and the inner side of the ring. The values of the diameter of the ring D_i and of the diameter of the kiln D_k are very close, the difference between them being called gap.

While the kiln is working, the gap may change, the main reason being the difference between the temperatures at which the two entities work.

The gap has to be kept between two margins so that the force of friction is great enough to avoid uncontrolled sliding between the ring and the shell. If these are not equal for all of the rings, they can twist the kiln. The contortion of the kiln leads to an overstressing of the shell which can have some negative effect on the lining of the kiln, which can deteriorate. Here from ensues the need to control the gap while the kiln is working.

The measurement of the temperature of the shell and of the kiln, and the computing of the gap based on these two are difficult, because the materials of which expansions have to be computed are inhomogeneous or have unknown thermal coefficients. The purpose of this work is to build up a measuring system for the gap, based on the measurement of the time of an entire rotation of the two entities using a programmable logic controller (PLC) of the class S7-300. It is not possible to obtain a great precision for the physical quantities and the periods of time, respectively, to be measured. For this reason the activity time of a step from a SFC routine was used.

The method described below is used practically to control and survey the clinker preparation kilns at the cement mill in Hoghiz.

2. The algorithm which determines the gap

The distances covered by the ring and the shell for n entire rotations are:

$$d_i = n \cdot \pi \cdot D_i; \quad d_k = n \cdot \pi \cdot D_k. \tag{1}$$

The linear speeds of the two entities are equal in point A (figure 2):

$$v_k = v_r, \tag{2}$$

ensuing:

$$\frac{\pi \cdot D_k}{T_k} = \frac{\pi \cdot D_r}{T_r} \tag{3}$$

where T_r is the period of time in which the ring accomplishes an entire rotation, and T_k is the period the time in which the shell of the kiln accomplishes an entire rotation.

In order to improve the computational precision of the gap, the times in which the two entities accomplish n entire rotations are measured.

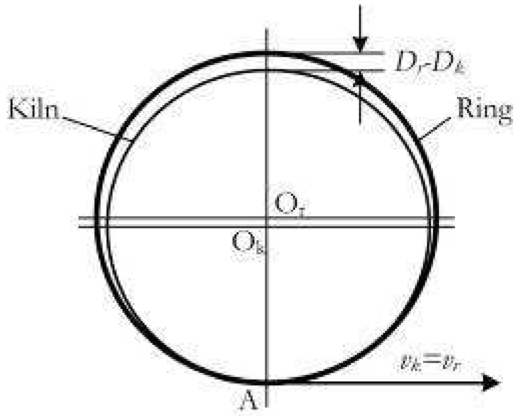

Figure 2. Mechanical parameters used to determine the gap

The distances covered by a point on these entities will be:

$$d_r = n\pi D_r, \tag{4}$$

respectively:

$$d_k = n\pi D_k. \tag{5}$$

Now, the difference between the distances covered by the two entities ensues by subtracting (5) from (4) and using (3):

$$d_r - d_k = n\pi D_r (1 - \frac{nT_k}{nT_r}) = n\pi D_r (1 - \frac{T_{nk}}{T_{nr}}) \tag{6}$$

where T_{nk}, respectively T_{nr} are the periods of time in which the shell and the ring accomplish n entire rotations.

Supposing the diameter of the ring D_i is known and that, because of the good heat-exchange conditions with the surroundings, it does not change significantly in time, $d_r - d_k$ can be determined by measuring T_{nk} and T_{nr}. It will be proved that this value is proportional to the mean value of the gap at the moment when the measurements are undertaken. Inserting D_r in the brackets of relationship (6) it ensues:

$$d_r - d_k = n \cdot \pi \cdot D_r \cdot \left(1 - \frac{T_k}{T_r}\right) = n \cdot \pi \cdot \frac{D_r \cdot T_r - D_r \cdot T_k}{T_r}. \tag{7}$$

Using relationship (3) equation (8) is obtained:

$$d_r - d_k = n \cdot \pi \cdot \frac{D_r \cdot T_r - D_k \cdot T_r}{T_r} = n \cdot \pi \cdot (D_r - D_k) \tag{8}$$

from here:

$$D_r - D_k = \frac{d_r - d_k}{n \cdot \pi} = D_r \cdot \left(1 - \frac{T_{nk}}{T_{nr}}\right). \tag{9}$$

The algorithm which determines the gap

consists of the following steps:

1. You determine the periods of time in which the two entities accomplish n entire rotations. In order to do this you have to mount mechanical transducers which discern the accomplishment of a rotation of the ring and of the shell. It is preferable to use mechanical transducers rather than proximity transducers because of the high temperatures around the mounting position, which could have a negative effect on their activity;
2. The gap is determined using relationship (9).

3. The computing program

In order to implement the algorithm shown above a PLC of the class S7-300 was used. Contact transducers were mounted closed by a groin anchored to the ring (`IRING1`), respectively to the shell of the kiln (`IKILN`). It is preferable to avoid using the timers to determine the period of time of n rotations because of the poor precision which is ensured by them. Therefore we have opted to measure the activity time of a step (`Si.T`), which is available for every instance of a routine written in the SFC language and which is measured in thousandths of a second.

For every transducer a procedure in SFC language will be written. In the program there will be a step which remains active from the moment the groin closes the contact for the first time and until this action takes place for the n^{th} time. The check will be done using the output of a counter (`CRing1` and `CKiln`), which becomes true after the accomplishment of n rotations, supposing the binary inputs are linked to the counting up input of the CTU counter and the preset value of the counter is n.

While the rotations are counted, the operator may change, of any reason, the reference speed. Any change of this kind must lead to a re-run of the counting operation. This check will be done using a routine which has the reference speed and the range in which this can vary as inputs and a binary variable (`SchV`) as an output, which becomes true if the range is exceeded. The reference speed will be acquired using an analog input and may be left in converter units as long as the range is also specified in converter units.

When the counting for the pair shell-ring is over, a computing routine has to be enabled, which determines the gap between those two and the analog value which has to be sent to the analog output and surveyed by the higher ranked system. The step which follows after the transition and which is enabled by `CRing1` or `CKiln` has to set the enabling variables of these routines (`VCR1, VCK`). This step must remain active until the computing is over or until the preset time to a new determination of the gap elapses. The transition which follows after this step may use a variable which becomes true at the end of the computing or a timer.

The routine for a ring is shown in figure 3.

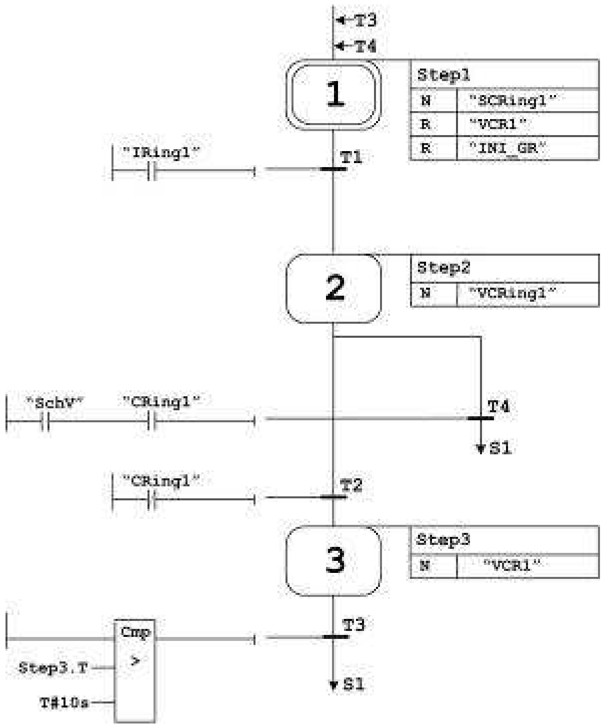

Figure 3. The routine which computes the gap

The cyclic program will contain two counters, which will count the *n* rotations for the ring and for the shell of the kiln, the call of the routine which checks the change of the reference speed of the kiln, the call of the routines which determine the time needed to accomplish *n* rotations and the call of the routine which computes the gap and sends it to the higher ranked system. The counters are enabled only if the second steps of two SFC routines are active, the variables used to enable the counters being `VCRing1`, respectively `VCKiln`.

The routine which computes the gap should only be called if the two SFC routines mentioned above have their third step active, namely when *n* rotations have been accomplished for the ring and for the kiln.

4. Conclusions

1. The computing algorithm has been applied to determine the gap for the clinker kiln at the cement

mill LAFARGE Hoghiz. In order to verify the obtained result, relationship (8) was used. Prior to switching on the kiln a line was drawn starting on the ring and ending on the shell of the kiln (figure 4a). When n rotations have been accomplished, we have measured $d_r - d_k$ (figure 4b) on the inner side of the ring; the gap is then determined by dividing this value by $n \cdot \pi$. The result has to coincide with the one obtained with the help of the PLC.

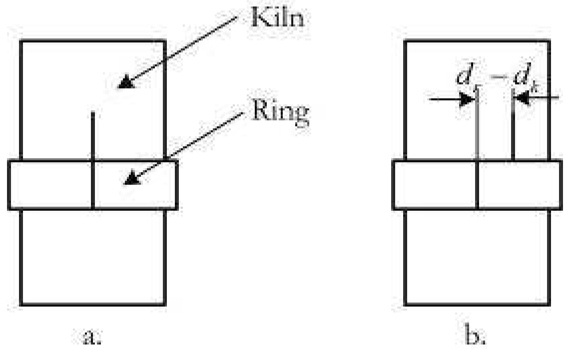

Figure 4. Figure explaining how the method has been verified

2. The precision of the determined gap depends on the number of rotations n. A detailed error analysis was not required as the performing of repeated measurements is not possible without stopping the production. An increase of precision can be noticed as the number of rotations taken into account has risen; the precision will settle around the value of 10 rotations. A further rise of this value can corrupt the results because, while the measurements are done, the shell of the kiln could expand significantly.

3. The data from the transducers have to be filtered because of the vibrations which appear for them ensuing from the fact that the rod anchored to the shell of the kiln is longer in order to protect the contact against the high temperatures of the shell and of the ring. In case of the binary variables, the filtering is done by a desensitization of the proper input for a period of time. The first rising edge of the input will set a bi-stable circuit which will be reset when the desensitization time elapses. In case of this application, a desensitization time of 5 seconds is enough. This time will have no influence on the results because the next useful rising edge appears only after more than 30 seconds.

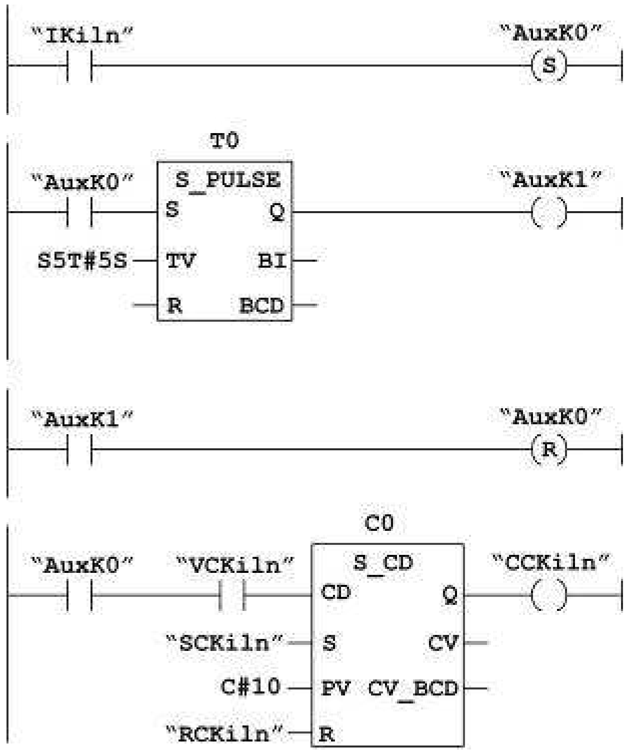

Figure 5. Software filtering of the signal `IKiln`

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