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Statistical Quality Control of Cement: A Case Study at Local Cement Plant

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Abstract:
Understanding, controlling and improving quality are key factors leading to business success, growth and enhanced competitiveness. Statistical quality control has significant contribution in this regard. This research work is about observing (checking) whether the process producing cement in local cement plant is in statistical control and estimating the process's capability. Twenty three consecutive data on the fineness of the cement powder were collected from the process of the grinding mill 2 of the plant. Using the data, the individual and moving range control charts were plotted. The analysis of the individual and moving range charts indicates that the process is in control whereas the capability ratio of the process shows the process is not capable.

Keywords: *Quality, statistical process control, cement fineness, control chart, capability*

1. Introduction

Quality has become one of the most important consumer decision factors in the selection among competing products and services. A business that can delight customers by improving and controlling quality can dominate its competitors. Quality is a competitive advantage (Montgomery, 2009).Therefore quality needs to be controlled. The purpose of quality control is to assure that processing is performed in acceptable manner. Companies accomplish this by monitoring process output using statistical techniques (Stevenson, 2005).

If a product is to meet or exceed customer expectations, generally it should be produced by a process that is stable or repeatable. More precisely, the process must be capable of operating with little variability around the target or nominal dimensions of the product's quality characteristics.Quality are inversely proportional to variability. (Montgomery, 2009).

In any production process, regardless of how well designed or carefully maintained it is, a certain amount of inherent or natural variability will always exist. This natural variability or "background noise" is the cumulative effect of many small, essentially unavoidable causes. Other kinds of variability may occasionally be present in the output of a process. This variability in key quality characteristics usually arises from three sources: improperly adjusted or controlled machines, operator errors, or defective raw material. Such variability is generally large when compared to the background noise, and it usually represents an unacceptable level of process performance (Montgomery, 2009).

In the production of cement the final step is to grind the clinker pellets (and added gypsum) into a fine powder. The resulting individual cement particles have a variety of angular shapes, and a wide range of sizes. The particle size distribution is critical for controlling the rate at which cement sets and gains strength (Hakan, 2006). There must be a certain amount of small particles to ensure that the cement sets in a reasonable amount of time; fineness of the cement

In Ethiopia, the construction industry is booming. As one of the important ingredients in this industry is cement, controlling the quality of cement produced is undoubtedly crucial. Toward this end statistical quality control has a significant contribution.

By defining fineness(which is accepted as a vital parameter by European and American standards) of cement as quality characteristic, SQC can be applied in controlling and improving the quality of the cement which in turn is contributing to the enhanced qualities of many of the concrete properties. This research is about applying the SQC in controlling the quality of cement produced in local cement plant by observing the variability level in the process.

2. Materials and Methods

2.1. Data Collection

This study used primary data. The data used in statistical monitoring were collected from a local cement plant. The data is on the fineness of the cement powder. A better parameter for describing the fineness of the cement (at least in terms of knowing how reactive it will be at early times) is the specific surface area, because most of the surface area comes from the smallest particles. The most common method for characterizing the surface area of cement is the Blaine air permeability test expressed in cm^2/g.

Consequently, data characterizing the surface area of cement (fineness) was gathered and analyzed.

The quality control department collects sample data on fineness of cement powder on hourly basis. The data collected is taken to laboratory for test.

Twenty-three consecutive data on blaine fineness of cement powder of cement mill 2 of the plant were obtained from quality control department.

2.2 Method of Data Analysis

The statistical quality control tool adopted is individual control chart. Situations in which the sample size used for process monitoring is n = 1, the control chart for individual units is useful. In applications of the individuals control chart, we use the moving range two successive observations as the basis of estimating the process variability. The moving range is defined as

$MR_i = | x_i - x_{i-1} |$

For the control chart for individual measurements, the upper control limit(UCL), t he lower control limit(LCL) and the central line(CL) are

UCL= averageX + 3*averageMR/d2
Central line = average X
LCL = averageX – 3*averageMR/d2
For the moving range chart
UCL= D4*averageMR
CL=average MR
LCL = D3*averageMR
Standard deviation = average MR⁄d2 where d2 =1.28 for n=2

Individual control chart and moving range chart are applied for the analysis of the data.

3. Results and Discussion

The data on the output of the mill on the fineness of the powder is shown below. The moving range is calculated using the difference between the consecutive data. The control charts are plotted for both the individual measurements and moving ranges.

Sample no	Fineness (cm2/g) (X)	Moving range (MR)
1	3818	
2	3828	10
3	3205	623
4	3938	733
5	3764	174
6	3424	440
7	3556	132
8	3616	60
9	3522	94
10	3536	14
11	3467	69
12	3522	55
13	3909	387
14	3530	379
15	4121	591
16	3841	280
17	3921	80
18	3844	77
19	3551	293
20	3715	164
21	3662	53
22	3894	232
23	3438	456

Table 1: Fineness Data
Average X=3679.217, Average MR=245.2727
Standard deviation = average MR/d2 =217.4404

3.1. Normality Plot

It is important to check the normality assumption when using the control chart for individuals. A simple way to do this is with the normal probability plot (Montgomery, 2009). The figure below shows the normal probability plot for the data on fineness of cement powder. The ordered observations are plotted against their observed cumulative frequency. It is drawn using Excel. .

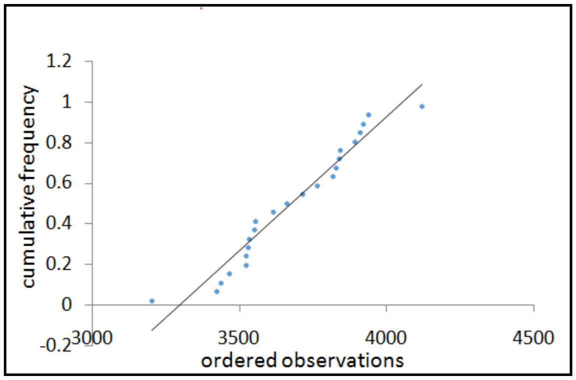

Figure 1: Normality plot

Since the plotted points are not deviating significantly and systematically from the straight line it canbe described approximately normal

Another way is using chi-square goodness-for-fit test for normality. Using chi-square test for normality at the 5% significance level, the p-value is 0.086.So the distribution is approximately normal

3.2. The Control Charts

The application of control charts gives information on two key aspects of the process: statistical control and capability

The individual control chart and the moving range chart are drawn for the data on the quality characteristic to see if the process is in control. The charts are plotted using Excel.

	The individual control chart	**moving range chart**
UCL	4331.538	801.306
CL	3679.217	245.2727
LCL	3026.896	0

Table 2: Three sigma control limits

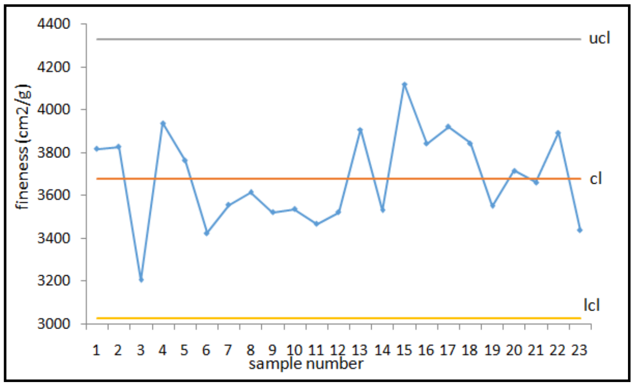

Figure 2: Individual control chart

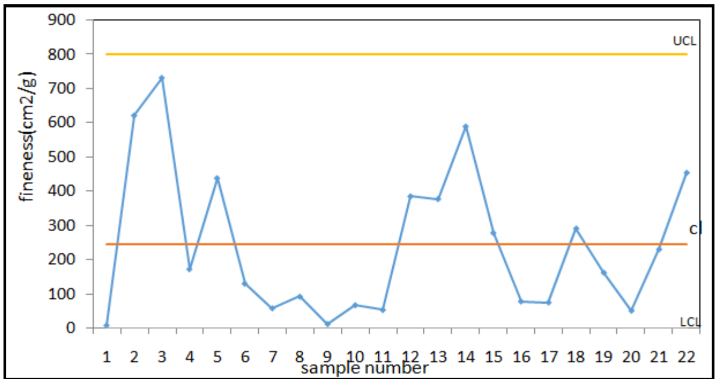

Figure 3: Moving range chart

Since there is no point plot outside the control limits and no obvious pattern or non randomness observed, the process is in statistical control. This means the process is operating with chance causes of variations which are inherent part of the process.

3.3. Estimating Process Capability

As the process is in control, it is possible to estimate its capability. It is customary to take the six-sigma spread in the distribution of the product quality characteristic as a measure of process capability.

The control chart can be used to describe the capability of the process to produce output relative to the specifications. The specification limits on fineness of cement are 3600 ± 100 cm2/g.

3.3.1. The Estimated Fraction of Nonconforming Outputs

$p = p\{x<3500\} + p\{x>3700\} = 0.66728$

The result shows that there are many non conforming units produced. The many non conforming units produced are indicative of the decision that intervention is highly required to reduce the variability in the process.

3.3.2. Process Capability Ratio

Since the process is not centered, Cpk is used

Cpk = min ((USL-process mean) / $3^*\sigma$, (process mean – LSL) / $3^*\sigma$)

= Min (3700-3679.217/3*217.4404, 3679.217-3500/3*217.4404) =0.03186

The specifications are tighter than what the process is capable of, so that even when the process is functioning as it should a sizable percentage of the output will fail to meet the specifications.

For a process to be deemed capable it must have a capability ratio of 1.33(Stevenson, 2005).The capability ratio of the grinding process is far below 1.33 indicating that the process is not capable.

4. Conclusion

It can be concluded that the process at cement grinding mill 2 of the plant is in statistical control whereas the process capability analysis shows that the process is not capable. Though the process is in control there is still high variability. It is necessary to reduce this variability. Variation in the production process leads to quality defects and lack of product consistency

It is necessary to intervene actively in the process to improve it. Experimental design methods, investigating specifications and changing process are helpful in this regard

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