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Various Control Charts to Monitor the Quality of Resistant Cement Production in the Kabaisa Cement Factory for the Year 2023

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Abstract

Control charts are an effective tool for statistical control of production quality processes by drawing samples from the production randomly and at specific time periods. In this research, different control charts were used for the purpose of monitoring the quality of resistant cement production in the Kubaisa Cement Factory, which is located in Al - Anbar Governorate. The weights of bags of cement (resistant cement) (which are measured in kilograms) were monitored using a new packing device, and after monitoring production for a period of (50) days in the months of November and December for a sample size of (5) units per day. The data was recorded on a regular and continuous period, , and the quality of production was examined by applying deferent statistical control charts . these charts are the arithmetic mean chart, the range chart, the standard deviation chart, the moving average chart, the Geometric Moving Average(GMA) chart . and Individual-Moving Range chart .The charts were applied using the statistical program (Minitab), and the results showed that the most of the charts were in control, with some notes.

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1. introduction

Since ancient times, interest has been in the quality of work, improving it, and completing it to the fullest extent, and one of the most important statistical measures to measure product quality is control charts, which are an effective tool that enables the decision maker to make appropriate decisions in an effort to reach the best performance of the production process, and it has a role in reducing the cost of the product, by Reducing defective units and knowing the factors affecting their quality and quantity needed. The efforts of scientists and researchers have emerged successively in paying attention to this field. Stewart (1767) is considered the first scientist to pay attention to the quality of employees performance, followed by Taylor (1880), who applied management with quality, followed by Fisher (1920), who supervised the first institute concerned with quality control, which was in India. As for Shewhart, he is one of the geniuses of statistics and he was the first One of the foundations of control charts in industry. The importance of quality control lies in verifying the quality of the user and product and that it is not affected by the required level of production and its ability to create a good competitive position. One of its procedures is to detect deviations and take appropriate action in this regard. Therefore, dashboards are considered one of the most important branches of statistics that have been widely used in the fields of production and manufacturing processes, especially after the use of modern technology techniques and the increased demand for production of superior quality, standard time, and specific budget.

1.1. Research problem:

The research problem can be summarized by answering the following questions:

1. Can it be said that the production process in the Kabaisa cement factory is statistically controlled?
2. Did the laboratory use quality control tools in the correct scientific sense?
3. What are the most prominent results of using quality control charts?

1.2. Research objective:

Applying several charts for statistical control of quality in order to improve performance in the Kabaisa Cement Factory in Anbar Governorate, detect deviations and abnormal values in the data that go beyond acceptable limits, and investigate the underlying causes and address them in order to obtain better production.

1.3. Reference review:

In 2013, Muhammad and Azouz [1] conducted an applied study on quality control using two types of analysis, horizontal and vertical, for one of the cement factories in Iraq for the month of June 2013, with normal distribution curves.

In 2016, Muhammad Hussein [2] conducted a case study at the Kirkuk Cement Factory with the aim of controlling the quality of the product, indicating that the quality rate in 2015 was higher than in 2014.

In 2018, Al-Taie and Al-Hamdani [3] used regression chart to control data from the Badoush Cement expansion plant, as the independent variable was working hours, while the dependent variable was cement production, and with a point beyond the control limit, the productivity rate was increasing.

In 2019, [4] Shehata and others presented research that dealt with control charts for a case study in a cement bag factory in Egypt. Variance analysis was used to reduce high variance and improve parameters of the percentage of spoiled production. Multiple linear analysis was performed for each characteristic to determine the best factors in improving production.

In 2020, Hassan et al [5] compared some statistical forecasting methods, taking the Kabaisa Cement Factory as a model for the study, with the aim of forecasting cement production using moving averages.

In 2021, Bashmani and Ali [6] conducted analytical research with the aim of monitoring the quality of the Tartous Cement Factory’s production, relying on descriptive analysis and preparing a questionnaire for this purpose.

2. Research Methodology

Statistical Process Control (SPC) has a major role in manufacturing processes and modern technology that measures quality and controls quality. Statistical process control operates numerous machines and tools to provide quality data from product measurements and process readings. Once collected, the data is evaluated and monitored to control the process.

Statistical process control is a simple way to encourage continuous improvement. When a process is continuously monitored and controlled, managers can ensure that it is operating to its full potential, resulting in quality manufacturing.

The concept of statistical process control emerged in 1924 when William Shuart designed the first control chart for statistical control. This quality control process was used extensively during World War II in ammunition and weapons facilities. Statistical process control monitors the quality of products without compromising on safety. Today, statistical process controls are widely used by the manufacturing sector around the world. Modern manufacturing companies have to constantly deal with raw material prices. Companies cannot control these factors, but they can control the quality of their products and processes. They need to constantly work on improving quality and efficiency to be a market leader.

Statistical monitoring is still the primary form of defect detection for most companies. With statistical process control, an organization can shift from being detection-based to prevention-based. By constantly monitoring process performance, operators can detect changing trends or processes before performance declines.

Control chart components [7]

Control charts show plotted points arranged chronologically around the midline. The midline (center) is determined

By averaging the observations, often around 30 to 50 observations, the upper (UCL) and lower control limits (LCL) are set at a distance of + or - 3 standard deviations from the plotted observations. UCL and LCL show the expected normal level.

There are many statistical control charts, each of which has a specific use depending on the nature of the research and the nature of the product's characteristics and features to be verified. For this reason, there are two types of statistical control charts: control charts for the variable (the variable has the quality of measurement) and control charts for specifications (they are indicative of... Features, not measurement) Due to the specificity of the research related to measuring the product in kilograms, the research was therefore focused on control charts according to the variables.

2.1.Control Charts for Variables [9] [8] [7]

These charts are used to control quality in cases where there is a characteristic of the quality characteristic of the product, and these measurements are such as product dimensional measurements such as length, weight of production units, amount of electric current, temperature, mass measurement, etc. There are several types of control charts for variables, and the common types of them will be explained. Which:

1. **The Arithmetic Mean Chart**

The arithmetic mean chart consists of the Upper Control Limit, written in abbreviated form (UCL), the Lower Control Limit, written in abbreviated form (LCL), and the Central Control Limit CL. It is calculated according to the following formulas:

$$UCL = \overline{\overline{X}} + A2\,\overline{R} \tag{1}$$

$$CL = \overline{\overline{X}} = \frac{\sum_{J=1}^{m} \overline{X_J}}{J} \tag{2}$$

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3}$$

$$UCL = \overline{\overline{X}} - A2\,\overline{R} \tag{4}$$

Since:

n: number of subgroups.

$\overline{X}$: The arithmetic mean of all subsamples (machines or tools)

m: main sample size (days)

($\overline{\overline{X}}$): the grand mean of the means of the subsamples.

2. **The Range Chart (R)**

The range chart consists of the upper limit, the lower limit, and the central limit, and the following formulas are used to calculate them:

$$UCLR = D4\bar{R} \tag{5}$$

$$LCLR = D3\,\bar{R} \tag{6}$$

$$CLR = \bar{R} \tag{7}$$

Since:
D4 and D3 are constants extracted depending on the sample size (n).

3. **Standard Deviation Chart.**

This method is a direct way to estimate the standard deviation of the arithmetic mean using the sample, especially in the case of the sample size between (10 - 12) observations or if the sample size is variable [6], and it follows the same steps in the arithmetic mean except for relying on the standard deviation instead of the range.

$$UCL = \overline{\overline{X}} + A3\,\overline{S} \tag{8}$$

$$CCL = \overline{\overline{X}} \tag{9}$$

$$LCL = \overline{\overline{X}} - A3\,\overline{S} \tag{10}$$

2.2. More Efficient Control Charts [11][10][9] [7]

1. **Moving Average (MA) Chart**

One of its most important functions is to reduce differences and reduce deviations from the arithmetic means, thus reducing the limits of control, which leads to the discovery of subtle changes. The chart is as follows:

$$UCL = \overline{\overline{X}} + 3\,\frac{\sigma}{\sqrt{nw}} \tag{11}$$

$$CCL = \overline{\overline{X}} \tag{12}$$

$$LCL = \overline{\overline{X}} - 3\,\frac{\sigma}{\sqrt{nw}} \tag{13}$$

2. **Geometric Moving Average (GMA) Chart.[14][13][12]**

In 1959, the scientist Robert used relative weight with exponential weighting to form a developed chart through which all deviations could be detected, even if they were small. The limits of the chart were as follows:

$$UCL = \mu_\circ + 3\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{14}$$

$$CLL = \mu_\circ \tag{15}$$

$$LCL = \mu_\circ - 3\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{16}$$

Regarding the averages, the formulas are as follows:

$$UCL = \overline{\overline{X}} + 3\sigma\sqrt{\frac{\lambda}{n(2-\lambda)}[1-(1-\lambda)^{2i}]} \tag{17}$$

$$CLL = \overline{\overline{X}} \tag{18}$$

$$LCL = \overline{\overline{X}} - 3\sigma\sqrt{\frac{\lambda}{n(2-\lambda)}[1-(1-\lambda)^{2i}]} \tag{19}$$

3. **I-MR-R/S (Individual-Moving Range) Between/Within chart**

The main outputs include I-chart, MR-chart, and R-chart or S-chart. The steps for this painting include:

- **The first step:** involves determining whether variation within the subgroup is dominant or not. Chart R or Chart S are used to evaluate variation within subgroups. An R or S chart is displayed depending on the subgroup size. When the subgroup size is 8 or less, an R chart is displayed. When the subgroup size is 9 or more, an S chart is displayed. An R chart plots the subgroup ranges. If the subgroup size is constant, the middle line on the R chart is the average of the subgroup ranges. If the sizes of the subgroups differ, the value of the center line depends on the size of the subgroup, because larger subgroups tend to have larger ranges. The control limits on the R chart, which are set at a distance of 3 standard deviations above and below the center line, show the amount of variance to be expected in the subgroup ranges. The S-chart plots the subgroup standard deviations. The mean line is the average of all standard deviations of the subgroup. The control limits on the S chart, which are set at a distance of 3 standard deviations above and below the center line, show the amount of variation expected in the subgroup standard deviations. The red dots indicate subgroups that fail at least one of the tests for special reasons and are not under control. If the same point fails multiple tests, the point is labeled with the lowest test number to avoid overlapping charts. If the chart shows out-of-control points, those points should be checked. Out-of-control points can affect estimates of process parameters and prevent control limits from truly representing the process. If the out of control points are due to special reasons, you should consider deleting these points from the calculations.

- **Second step:** Determine whether the subgroup difference is dominant or not
- **Third step:** Determine whether the process medium is dominant or not
- **Fourth step:** Identify the observations that got out of control in each test.

3. The applied aspect

This aspect concerned the actual application of all the control charts mentioned in Paragraph (2) on one of the cement manufacturing plants affiliated to the Iraqi General Cement Company, which includes many cement manufacturing plants. The Kabaisa cement plant was chosen to examine the quality of production, and ready-made statistical programming (Minitab 18) was used. To draw various control charts.

3.1. A brief overview of the Factory

Kabisa Cement Factory, which was established in 1981 in Anbar Governorate, Hit District, and its first production was in 1984. The factory manufactures regular Portland cement and has two production lines. It annually produces two million tons of cement using the dry manufacturing method.

3.2. Practical application of qualitative control charts for Kabaisa cement factory data in AL- Anbar governorate.

In the month of November 2023 at the Kabaisa Cement Factory, which is located in Anbar Governorate, the weights of bags of cement were monitored in units of (kilograms) for one of the products produced (resistant cement). A new packing device was used and after taking (50) samples of (5) units at regular intervals. The necessary statistical indicators were recorded and calculated, which are the arithmetic mean - range - standard deviation - variance, and for all subsamples, the results as follows :

$$\overline{\overline{X}} = \frac{\sum \bar{x}}{n} = \frac{2499.396}{50} = 49.98792$$

$$\bar{R} = \frac{\sum R}{n} = \frac{15.17}{50} = 0.3034$$

$$\bar{S} = 0.352671$$

$$d_2 = \frac{\bar{R}}{\bar{S}} = \frac{0.3034}{0.352671} = 0.860292$$

The following table summarizes the results:

Table (2): Some necessary statistical indicators for the research sample data

The sample	$\bar{x}$	R	S	S^2	The sample	$\bar{x}$	R	S	S^2
1	49.986	0.3	0.364903	0.133154	**26**	49.982	0.31	0.388455	0.150897
2	50.03	0.39	0.39823	0.158588	**27**	49.94	0.37	0.376997	0.142127
3	50.044	0.39	0.433547	0.187963	**28**	49.954	0.07	0.164373	0.027019
4	49.99	0.3	0.343672	0.11811	**29**	49.936	0.4	0.409536	0.16772
5	49.96	0.34	0.361881	0.130958	**30**	50.002	0.37	0.651825	0.424876
6	49.918	0.16	0.270071	0.072938	**31**	49.964	0.25	0.392652	0.154175
7	50.018	0.3	0.361458	0.130652	**32**	50.078	0.35	0.392238	0.153851
8	49.944	0.4	0.405847	0.164712	**33**	49.966	0.36	0.3692	0.136308
9	50.004	0.36	0.375731	0.141174	**34**	49.916	0.38	0.39413	0.155338
10	50.072	0.26	0.325097	0.105688	**35**	50.022	0.23	0.30775	0.09471
11	49.98	0.33	0.365006	0.133229	**36**	49.916	0.34	0.365928	0.133903
12	49.972	0.39	0.432438	0.187003	**37**	50.018	0.3	0.340042	0.115629
13	49.918	0.35	0.388881	0.151228	**38**	49.968	0.34	0.403356	0.162696
14	50.01	0.34	0.393598	0.154919	**39**	49.95	0.19	0.282289	0.079687
15	49.942	0.11	0.225156	0.050695	**40**	50.056	0.16	0.270197	0.073006
16	49.992	0.39	0.411488	0.169322	**41**	50.08	0.25	0.321997	0.103682
17	49.986	0.26	0.315275	0.099398	**42**	49.994	0.4	0.401862	0.161493
18	49.984	0.25	0.32517	0.105736	**43**	50.104	0.23	0.331182	0.109681
19	50.048	0.34	0.385653	0.148728	**44**	50.058	0.39	0.438196	0.192016
20	49.946	0.29	0.327685	0.107377	**45**	49.956	0.28	0.337859	0.114149
21	50.024	0.32	0.355822	0.12661	**46**	49.926	0.34	0.37287	0.139032
22	50.05	0.3	0.356487	0.127083	**47**	49.91	0.2	0.298601	0.089163
23	50.088	0.39	0.397516	0.158019	**48**	49.964	0.31	0.344775	0.11887
24	49.886	0.16	0.246299	0.060663	**49**	49.94	0.29	0.335369	0.112472
25	49.986	0.34	0.348082	0.121161	**50**	50.018	0.3	0.361458	0.130652

3.3. Building control charts

1. Arithmetic mean chart

$\mathrm{UCL} = \bar{\bar{X}} + A_2\,\bar{R} \rightarrow \mathrm{UCL} = 50.461078$

$\mathrm{CCL} = \bar{\bar{X}} \rightarrow \mathrm{CCL} = 49.98792$

$\mathrm{LCL} = \bar{\bar{X}} - A_2\,\bar{R} \rightarrow \mathrm{LCL} = 49.514762$

$A_2 = 1.559518$

Note that:

(UCL): Upper Control Limit

(CCL): Central Control Limit

(LCL): Lower Control Limit

Through the upper and lower control limits, we can notice that the process is under statistical control. Because all observations are within limits the arithmetic mean chart is drawn as in the following figure:

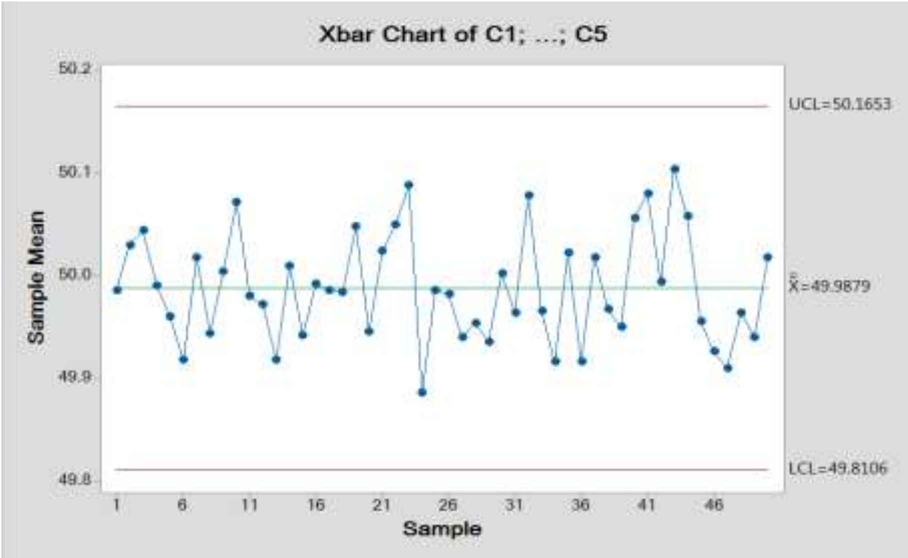

Figure (1): The arithmetic mean chart of the research sample data

From the figure above, we notice that the process took place under statistical control because all points fall between the upper and lower limits of control.

2. R-Chart (Range Chart)

The following range chart was obtained, as shown in the figure below:

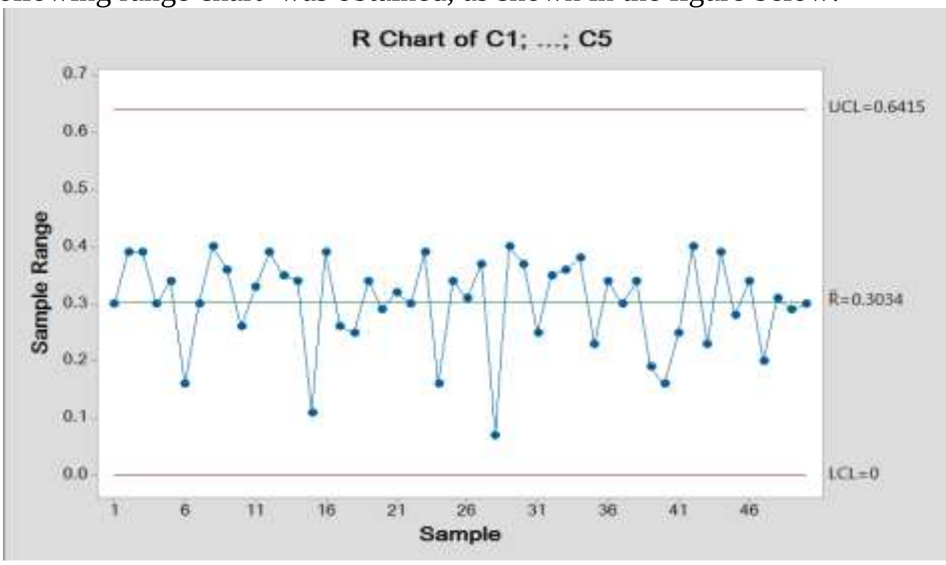

Figure (2): Range chart for the research sample data

From the figure above, we notice that the process is under control and all observations are far enough from the upper and lower control limits. It is also noted that there is more distance from the upper control limit than from the lower control limit. There are 25 observations located above the control line and 16 points that fell below the control line while it was There are 9 sightings that occurred on the Line of Control.

3. Standard Deviation Chart

Figure (3) indicates that the process is under control according to the standard deviation chart. The figure also indicates that the data is more distant from the upper control limit than from the lower control limit. It is also noted that observation No. 28 is the closest observation to the lower control line.

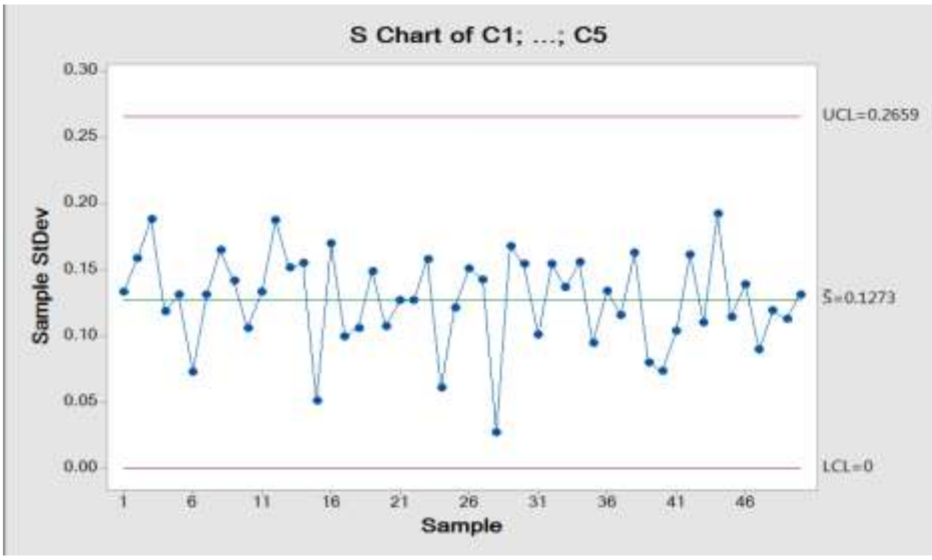

Figure (3): Chart of standard deviation of research data

4. Moving Average Control Chart

Figure (4) confirms that the entire production process is under statistical control according to the moving averages chart, noting that the spread of the data was similar between the upper and lower limits of control.

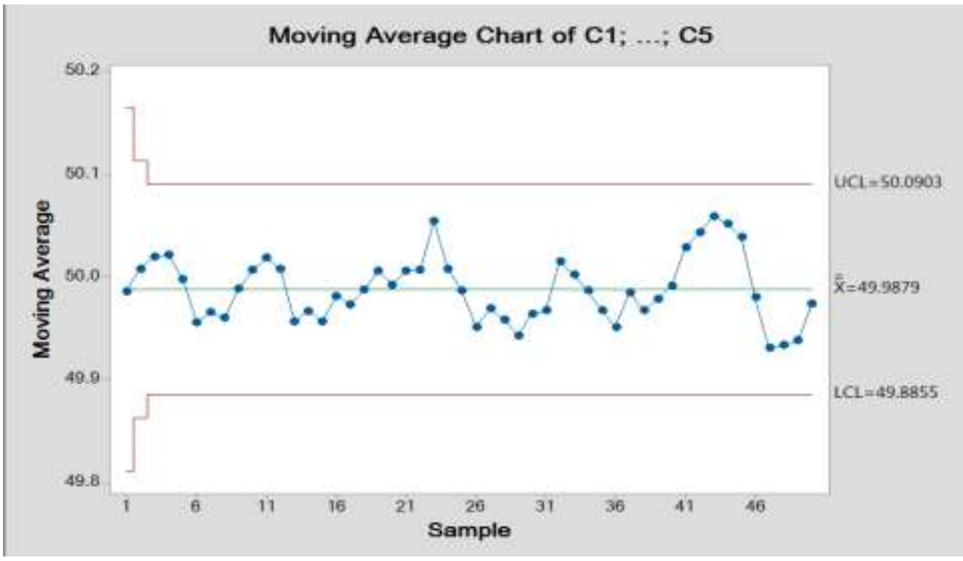

Figure (4): Moving Average Chart

5. Geometric Moving Average (GMA) Chart

From Figure (5), we also notice that the process is under control according to the exponential weighted moving average control chart (Geometric Moving Average), noting that the observation is closer to the upper limit than the lower limit, and the emergence of observation No. 44 is the observation closest to the upper limit of control chart .

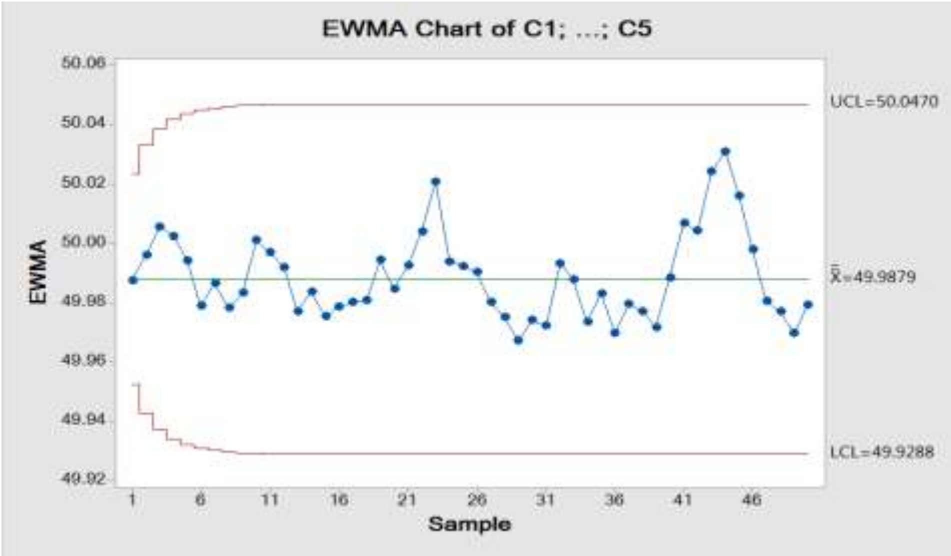

Figure (5): Geometric Moving Average (GMA) Chart for research data

6. Single Moving Range Chart I-MR-R/S (Between/Within)

To monitor the stability of the process over time, we use the I-MR-R/S (Between/Within) chart to identify and correct instabilities.

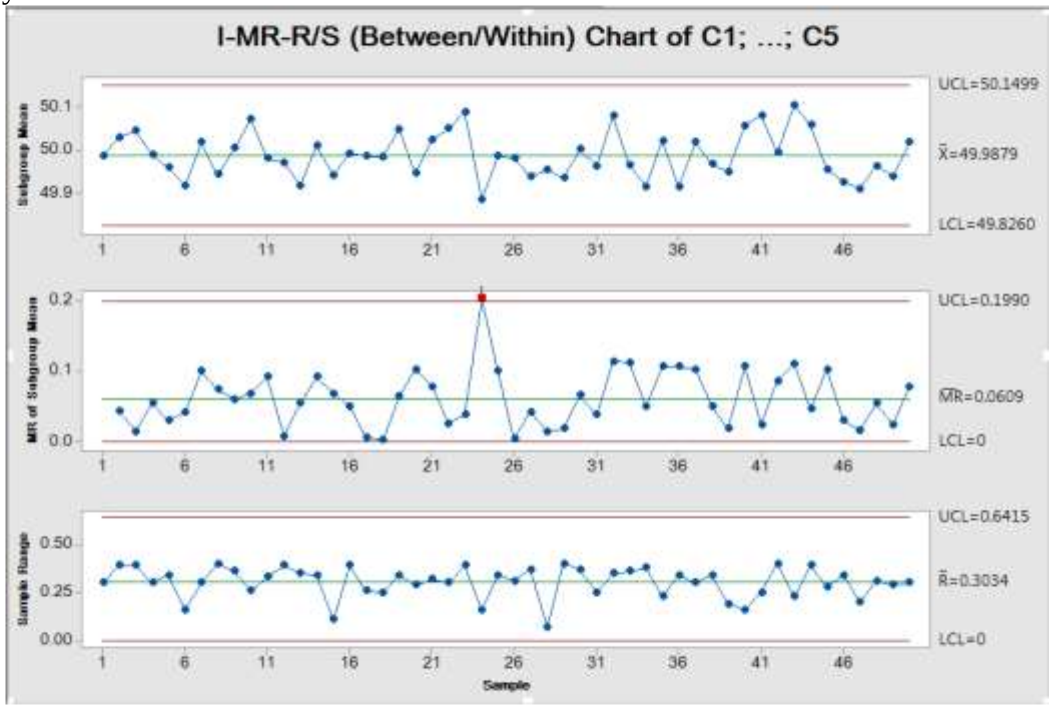

Figure 6: I-MR-R/S (Between/Within) chart for data

From Figure (6), we notice that one observation got out of control in the moving range test chart, which is observation No. (23). This means that one of the moving averages of the subgroup is not stable over time, perhaps for special reasons, and in this case this observation must be excluded. Likewise, it is not possible to control the variation between and within the subgroups, and therefore the chart does not give evidence of loss of control.

4. Conclusions

Through the research results, the following was reached:

1. The use of statistical control tools had a clear impact in controlling the production process and identifying non-conforming cases, the state of instability in the process average, and the effect of the change in the standard deviation, which helps in knowing the causes in order to take the appropriate action to return the production process to the limits of control.

2. All control charts were under control except for the moving range chart for the subgroup. The observation No. 23 was out of control, which means that it is unstable over time and may affect the estimation of process parameters and prevent the process boundaries from being represented correctly. The out-of-control point may affect the Parameter estimates and prevent control limits from being represented correctly. It may be due to special reasons, and this case can be treated by excluding the observation from the process.

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لوحات سيطرة مختلفة للرقابة على جودة انتاج الاسمنت المقاوم في معمل اسمنت كبيسة لعام 2023

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المستخلص

لوحات السيطرة أداة فعالة للسيطرة الإحصائية على عمليات جودة الانتاج عن طريق سحب عينات من الإنتاج بشكل عشوائي وبفترات زمنية محددة، في هذا البحث تم استعمال لوحات سيطرة مختلفة لغرض الرقابة على جودة انتاج الإسمنت المقاوم في معمل اسمنت كبيسة والذي يقع في محافظة الانبار. اذ تمت مراقبة اوزان اكياس الاسمنت بوحدة قياس الكيلوغرام لمنتج (الاسمنت المقاوم) باستعمال جهاز تعبئة جديد وبعد مراقبة الانتاج لمدة (50) يوم من شهري تشرين الثاني وكانون الأول لعينة بحجم (5) وحدات يوميا، وقد تم تسجيل البيانات بفترة منتظمة ومستمرة، وتم فحص جودة الإنتاج من خلال تطبيق لوحات سيطرة احصائية مختلفة، وهذه اللوحات هي هي لوحة الوسط الحسابي ولوحة المدى ولوحة الانحراف المعياري ولوحة المتوسطات المتحركة ولوحة الوسط الحسابي الموزون اسيا ولوحة المدى المتحرك الفردي. وتم تطبيق اللوحات باستعمال البرنامج الاحصائي (Minitab) واظهرت النتائج ان غالبية اللوحات كانت تحت السيطرة مع بعض الملاحظات .

معلومات البحث

تواريخ البحث:

تاريخ تقديم البحث:22/2/2024
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الكلمات المفتاحية:
لوحات السيطرة، المدى المتحرك الفردي، GMA، معمل سمنت كبيسة

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