International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-4, April 2019

Quality of Chrome Plated Compression Rings: An Empirical Study Paper Title Name

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Abstract: The chrome thickness data would be acquired using a delta-scope in case of plain compression rings. A process with measurement errors becomes incapable in making improvements to the process and may make matters worse. In the process of obtaining measurements and data there may be variations and produce defects. This paper aims at the quality control aspects of chrome plated compression rings and increase the quality levels of the rings. The control charts of Shewart were used to check whether the thickness is within the standards. Further, Analysis of variance (ANOVA) is used to test whether the measurement of thickness in at the three different positions is significantly different or not. It was observed that, from the X –bar chart, all the averages of the cells are falling within the control limits for all the positions and so the process in control and the average thickness of the rings in all cells are within the specified limits whereas from the Range Chart, the range values of the cells are falling within the control limits for 3'O clock position and 6'O clock position but not in the case of 9'O clock position. Further from ANOVA there is no significant difference in the thickness at all the three positions

***Index Terms*: Chrome coating, control charts, quality, ANOVA**

I. INTRODUCTION

Automobiles have been around since 1808. The first car powered by an internal combustion engine was designed by Francois Isaac de Rivaz. It was Karl Benz in 1885, who developed the petrol-powered automobile which was considered to be the first production car. Internal combustion engines are discernibly the most important components for any automobile. May it be a motorcar or an aircraft. Internal combustion engines are the power houses of every kind of automobile there is. Today, since a long time, internal combustion engines are used in all land, sea and air vehicles. Though the construction and design details differ for each type of application, the basic working principle remains the same. Air and fuel are mixed and sent into a combustion chamber: which is supposed to be perfectly air tight; and combusted with the help of a heat source (spark plugs; only in case of petrol engines). The products of this combustion process should be carefully guided to the outside of the engine; failing which, there would be a lot of turmoil and commotion leading to complete engine failure. DieselNet (2016). The major parts of an internal combustion engine comprise of pistons, piston rings, gudgeon pins, connecting rods, crankshaft, cam shaft(s) intake and exhaust valves and manifolds, cylinder sleeves, spark plugs (petrol), crank case. Pistons are the main parts which undergo linear reciprocating motion due to the combustion forces, transferring motion from the combustion thrust to the crank shaft via the connecting rods1. The combustion process takes place in the volume between the valves and the piston inside the cylinder. In order to prevent combustion gases from seeping into the crankcase which may lead to various problems like contamination of engine lubricant, loss of torque, loss of power, loss of fuel economy and so on; perfect air tight sealing has to be achieved. Piston rings play a major role in doing so. They sit in the grooves present on the surface of the piston which is in contact with the cylinder wall, essentially nullifying the contact between the piston and the cylinder wall. Hence, it is observed that the first major function of a piston ring is to maintain the sealing between the combustion chamber and the crank case and also to reduce the friction generated between the piston and the cylinder wall essentially by reducing the area of contact. There are many more functions a piston needs to carry out. As the piston rings have a very small or; in perfect scenarios; no gap from the cylinder, it can be helpful in maintaining the right amount of lubricating oil in between itself, the piston and the cylinder wall. The rings which are designed to do this specific operation apart from partly contributing in sealing the combustion chamber from the crank case; are called oil scrapper rings. The rings which are designed to solely perform the function of sealing and are placed in the top most grove (towards the combustion chamber) are called Compression rings, or simply Top rings. In highly demanding high performance application, another type of ring apart from these are used; which is placed in between the top rings and the oil scrapper rings. The oil scrappers are always at the bottom, the reason being; the oil is in large quantities present in the crank case (also referred to as the oil sump). Being placed close to the oil aids the ring to perform it function more effectively. It is also known that there is a gap in the circumference of the ring. Considering the amount of time for which a ring has to perform its job, the ring gap is designed in such a way that the pressure exerted by the surface of the piston ring on the cylinder wall is always at its maximum. Ring gap, along with the ovality are the major parameters which decide where it would be used.

Manuscript published on 30 April 2019.
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A ring with negative ovality: the case of ovality where the pressure exerted by the ring is minimum near the edges of the ring gap; would be best suitable in case two stroke engines. Whereas, a ring with positive ovality is best suitable for Four stroke engines. It can be said that, the more the ovality, the more pressure the ring surface exerts on the cylinder wall and vice versa. Ring gap, has another function too. Despite the fact that rings are meant to provide perfect air tight sealing, the presence of this gap; enables the circulation of lubricating oil throughout the surface of the cylinder. as reducing friction between the piston and the cylinder is one of the primary functions of the piston rings, a few applications demand the extreme. The friction reductions achieved by reducing the contact surface and circulating lubricating oils are just not sufficient in certain applications2. Racing engines are special applications which demand much less friction in between their parts. This leads to the need to reduce the native friction that exists between the surface of the piston rings and the cylinder sleeves due to the materials used. Both are usually made of grey cast iron. This leads to the need to implement surface finishes on both cylinder sleeves and piston rings. Cylinder sleeves are usually manufactured using a process called honing; which produces a smooth enough surface.

In case of rings, another special type of surface finishing is required. Electroplating is one of the most vastly used methods to coat one material on another. Molybdenum is the most widely used plating material for various types of piston rings as it provides excellent wear and scuff resistance. Tungsten Carbide (for hard liners), and chrome are materials which are also widely used for piston ring coating, depending on the application. Chrome-plated rings are commonly used in environments with high particulate matter like dirt tracks. Chrome-plated rings work best when mated to cast iron surfaces but not so well with chrome plated bores or hard faced cylinder bore liners which may be coated with nickel/carbide coatings. All types of rings can be plated with any material. Molybdenum, Chrome or Tungsten Carbide. As mentioned earlier, rings are classified based on their primary function and positioning3. Highlight a section that you want to designate with a certain style, and then select the appropriate name on the style menu. The style will adjust your fonts and line spacing. **Do not change the font sizes or line spacing to squeeze more text into a limited number of pages.** Use italics for emphasis; do not underline.

II. Literature Review

The rings are widely coated based on the running conditions. For example chromium coating is used in rough and destructive. The chrome plating is hard for the compressor ring. For piston rings the surfaces are not only plated with chrome but also thermally sprayed with molybdenum, metal composites, metal-ceramic composites or ceramic composites uniformly (Mollenhauer, 1997). Thermal spraying composition has included molybdenum-nickel-chromium alloys, chromium oxide (Cr_2O_3) with metallic chromium binder, Alumina-Titania (Al_2O_3-TiO_2), tungsten carbide (WC) with metallic cobalt binder, $MoSi_2$, CrC-NiCr (Dufrane, 1989, Radil, 2001). By spraying chromium ceramic on the ring surface hard chromium layers can be improved by the thermal load capacity can increase (Rastegar and Richardson, 1997)

Multilayer titanium nitride (TiN), coatings deposited onto cast – iron piston rings are claimed to be more wear resistant than a chromium plated or phosphate surface, given, the number of layers is high (Zhuo et al., 2000). for low-heat rejection engines, Haselkorn and Kelley (1992) have investigated various types of coatings. They found that high carbon iron-molybdenum blend and chrome-silica composite applied by plasma spray, and further chrome nitride applied by low-temperature arc vapor coatings have properties that show promising characteristics in low-heat rejection engines (Haselkorn and Kelley, 1992). In selected cases, the entire piston ring surface can be treated with coatings based on phosphorous, nitrides, ferro-oxides, copper and tin (Federal Mogul, 1998, Mollenhauer, 1997) Chromium is rough and contains hundreds of microns and can reach a millimeter. It is used to cover the cylinder, the piston segments with internal combustion engines, cutting tools, molds and dies, the plates stereotypes of rotative presses. (. Greenwood, 1971, Marinescu etal., 1984, Angelescu, 2002). Chromium coatings are characterized by high corrosion resistance, low coefficient of friction, high hardness and wear resistance. The coatings protect steel in humid atmosphere, in sea water, acidic or alkaline environments oxidizing, ammonia, hydrogen sulfide, gases.(Corrosion Science, 1973, Bardac,et al, 2005, Mitelea et al,1987) Hard chrome ion plating of Piston Ring was introduced during World War II in an aircraft engine as it significantly reduces wear and friction in piston ring. Hard chromium coating was used in surface treatment of piston ring for both gasoline and diesel engine and also for the compressor (Ondřej, 2012).

Types of Rings:

Compression Rings:

The compression ring is the first in order from the top surface of the piston that is on the side of the combustion chamber. Compression rings seal the combustion gases within the combustion chamber/ cylinder and prevent leaking down into the crankcase. It also transfers heat from the piston to the cylinder walls. Due to its positioning, it is sometimes referred to as the top ring in some engines3.

Intermediate / Scraper Rings: Scraper rings are placed in between the top compression rings and the bottom most oil control rings. Scraper rings control the amount of oil that stays on the surface of the cylinder. These rings are designed to maintain the exact amount of oil on the cylinder walls required for the compression rings to be properly lubricated and also to seal the combustion gases and heat within the combustion chamber to some extent.

Oil Control Rings:

These rings are placed at the bottom of the piston. The main function of oil rings is to control the amount and economy of the lubricating oil. They ensure oil is evenly spread on the cylinder walls.

Some engine designs may have compression rings and oil rings only. In such engines, the compression rings are called top compression ring and the second compression ring. The second compression ring would have to designed to both seal in the combustion gases within the combustion chamber and to scrape oil on the cylinder walls.

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The cross-section of the rings varies from rectangular to taper faced rings. For a very long time, the secondary function of the piston rings has always been to reduce friction in engines thus increasing cylinder life. This reduction in friction and good compression due to well-designed compression rings has also resulted in increased power and engines with relatively higher efficiency.

Chromium has various advantages like high wear resistance due to reduced friction and resistance to corrosion, given, the coating done should be of high quality – accurate and even thickness of the coating throughout the mating surface of the piston to be able to operate under all conditions inside the engine without damaging or peeling off or breaking.

Chrome plating

Chrome coating of piston rings is predominant among racing and dirt track engines as it reduces friction and improves wear resistance. Many stock engines are also equipped with chrome plated cast iron or steel top rings. Chrome rings are widely used in dirt track engines because dirt does not stick to chrome and scour the cylinders. Hence a greater resistance for airborne contaminants can be achieved through chrome plating of piston rings3.

Importance of Thickness

Piston ring groove

The piston ring belt consists of three ring grooves and the piston rings are situated in these grooves between the ring groove flanges. In order to increase the wear resistance of the ring grooves in the pistons of heavy fuel engines, hard chrome plating is used in the grooves (Dowson, 1993).

The thickness of this electroplated material on the piston ring has to be decided very carefully. If it is too low, it may lead to a case where chrome plating was completely useless. If too high, it would affect the magnitude of pressure that the ring exerts on the cylinder wall.

This gives a rough estimation of the precision required to manufacture such a demanding part. The precision involved in the manufacturing of piston rings escalates to a level of micrometers in most common application and nanometers in highly demanding applications. All dimension of a piston ring has tolerances in the order of hundreds of microns (micrometers). In case of chrome electroplating, the thickness of material deposited on the ring is in the order of a few hundreds of microns. The tolerance values go to the order of tens of microns which means higher precision.

Piston rings chrome plating process

Coating of piston rings with chromium is an electro-chemical process done after almost all the mechanical machining processes are done. Most of the piston rings are rectangular or trapezoidal in cross-section. Contrary to the geometrical definition of a ring, a piston ring is not a complete geometrical circle. Instead, a gap is cut in the circumference of the ring of about 2 mm to 10 mm depending on the application. This gap is to account for the thermal expansion caused due to high combustion temperatures inside the engine cylinder.

Chrome coating process

As mentioned earlier, piston rings are not complete closed circles, instead a gap is cut in their circumference. Hence, inherently, two values of diameters can be observed, first, when the ring is in the normal state; i.e., the gap is let open as it is, and secondly, when the gap is forcefully closed with the help of an external force. The diameter of an open piston ring is hereby referred to as the open diameter, and the diameter of a piston ring closed forcefully as closed diameter.

After all the mechanical machining processes are done, the rings are brought into the chromium coating facility, and are loaded onto long steel rods called arbours. An insulating protective material is coated onto the inner surface of the rings to ensure they are not coated with chromium. Then, the arbour loaded with insulated, but open piston rings is loaded into a hydraulic press, where gaps of all the loaded rings are closed simultaneously, so that the arbour can be sealed with two plates of diameters equal to that of the closed diameters of the loaded rings.

Chromic acid tanks

In the chrome coating facility, there are two rows of chromic acid tanks with two tanks each. Each tank is further divided into four cells, wherein one arbour can be loaded. An arbour has to be connected to a power source and a control panel. The voltage, current supply to a specific arbour in a cell, and the duration for the same is monitored and controlled from the control panel. As soon as the arbour is loaded into the cell, the required current, voltage and duration settings are entered into the control panel. After the duration, the power supply to that particular cell/arbour is automatically shut down by the control panel.

These arbours are then manually unloaded from the tanks and are sent for further finishing processes.

Process of measurement of chrome plating

As the thickness of the chrome coating is a major quality aspect, insights are required about how exactly the chrome thickness is measured. Both destructive and non-destructive tests (NDTs) are used to measure the thickness of chrome plating achieved. NDTs are mostly performed on plain rings; whose surface in contact with the cylinder does not have any grooves i.e., which are not oil control or scrapper rings. In simpler terms, only top/compression rings chrome thickness can be measured with a simple instrument known as Delta scope non-destructively.

In case of Oil control/scrapper rings, the ring has to be broken into pieces and then the chrome thickness can be measured using a microscope. This is the Destructive test.

Control Charts

The variation within processes is analyzed using control charts. There are various types of charts depending on the type of measurement used. Since we are measuring the thickness of Chrome using a deltascope which is in microns we construct the X-bar and range chart and X-bar and standard deviation chart to check whether the thickness is within the standards(Shewart,1920).

The X-Bar chart shows how much variation that occurs in the process over time. The Range (R) chart shows the variation within each variable (called "subgroups"). The process is said to be statistical control if all the average values lie between the lower and upper control limits and then the process is predictable..

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When an X-Bar/R chart is in statistical control, the average value for each subgroup is consistent over time, and the variation within a subgroup is also consistent. Control limits for both X-bar chart and the range chart are not same as specification limits, but both are important when we are performing process analysis. Similarly the control limits for both X-bar chart and the standard deviation chart are not same as specification limits. Control limits are characteristics of the process. They reveal the actual amount of variation that is observed. We assume that the variation follows the normal distribution, which means that 99.73% of all of our observations will fall somewhere between three standard deviations below the mean (-3・) and three standard deviations above the mean (+3・). We use this principle to set our control limits.

III. METHODOLOGY

Data Acquisition

In each arbour, only one type of rings can be loaded at once. Rings of a single type are loaded onto several arbours depending on the number of rings that need to be coated and are placed into several cells sequentially by an operator. Hence, the arbours loaded with the same type of rings are not loaded or unloaded into cells at the same instant. The arbours are unloaded from their respective cells in the same sequence as they are loaded. As the concentration of the chromic acid in the tank may vary with depth and the current passing through the arbour may vary with the length (height) as it offers some resistance to current flow, samples are collected from the top, middle and bottom ends of the arbour. For a bigger sample of data, three rings are picked from each region (top, middle and bottom ends). These three rings are not necessarily the first three from the top of the arbour. Instead, three random rings are randomly picked from each arbour region. Each ring is then subjected to non-destructive testing to find the thickness of coated chrome using a delta scope, yielding results in microns (micrometres). The chrome thickness of each ring is measured non-destructively using a deltascope, at three different positions on the ring. Considering the center of the ring gap to be the zero-degree mark for the angular measurement, thickness is measured at three points on the plated surface of the ring, 90 degrees(3’O clock position), 180 degrees(6’O clock position) and 270 degrees(9’O clock position); once again, in order to ensure quality of chrome plating throughout the surface of the rings which has to be plated. Doing this would produce three data points. The thickness of chrome plating measured at three different points on a single piston ring. But, in order to properly analyze the overall quality of chrome plating, a larger data set is required. In order to achieve this, data points from 13 cells are taken, resulting in a data with 234 data points. This data is then laid out in an Excel Spreadsheet.

X-bar and R charts

To determine the control limits, we apply the following formulas, where X with a double bar indicates the average of all the X-Bars, and the constants A2, D3, and D4 are selected from the table based on the number of items in each of your subgroups:

For inspection orders where the item characteristic is a stable sample size, you must consider each individual sample as a sub-group.

Calculate the average of measured value for each sub-group.

$\bar{x} = (x1+x2+\ldots\ldots+xn)/n$

Where $\bar{x}$ = the average of the number of measurements within each sub group

x1,x2,……xn are the individual measurements within a sub group,

n is the number of measurements within a sub group

Calculate the range of measured value for each sub-group:

$\bar{R} = (R1+R2+\ldots\ldots..+ Rk)/k$

Where Ri is the individual range for each sub group

$\bar{R}$ is the average of the ranges for all subgroups

K is the number of sub groups

Range (sub-group) = Largest Measured Value (sub-group) - Smallest Measured Value (sub-group)

Calculate the mean of each subgroup's average. The mean of each subgroup's average is the centerline in the chart.

$\bar{\bar{X}} = (\overline{(x1)} + \overline{(x2)} + \ldots \overline{(xk)})/k$

Where $\bar{\bar{X}}$ is the grand mean of all the individual sub group averages

$\bar{x}$ is the average for each subgroup

K is the number of sub groups

Calculate Upper Control Limit (UCL) and Lower Control Limit(LCL) for averages of subgroups. Use the following formula to calculate the limits .

The Upper Control limit UCL = $\bar{\bar{X}}$+A2$\bar{R}$

The Lower Control Limit = $\bar{\bar{X}}$- A2$\bar{R}$

The above limits are calculated based on A2 value (from Factors for Control Limits) for the corresponding sub-group (sample) size N.

The range limits are calculated using D3 & D4 values for corresponding sub-group size N. These limits are plotted in the control chart. Calculate the control limits for the Ranges, using this formula:

Analysis

The control charts (X-bar) are constructed for three positions 90 degrees(3’O clock position), 180 degrees(6’O clock position) and 270 degrees(9’O clock position)

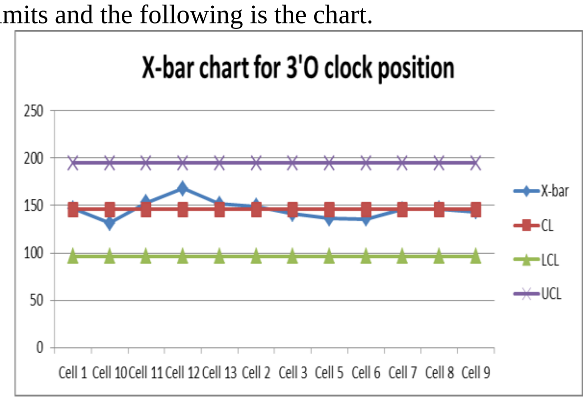
For 3’O Clock Position for a standard value of A2 = 1.287 from the standard table of control charts, the following are the control limits

UCL = 194.796

LCL = 96.66229

CL = 145.7292

The averages of each cell are plotted along with the control limits and the following is the chart.



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From the above chart we observe that all the averages (x-bar values) of the cells are falling within the control limits; the upper control limit and the lower control limit. This indicates that the process in control and the average thickness of the rings in all cells for the 3'O clock position are within the specified limits.

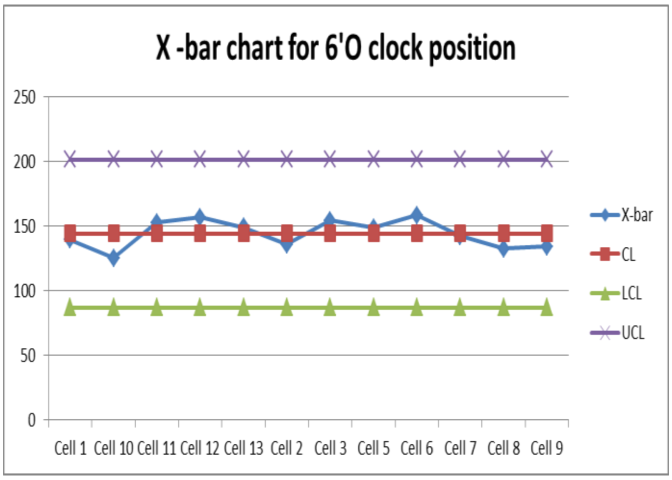
For 6'O Clock Position for a standard value of A2 = 1.287 from the standard table of control charts, the following are the control limits

UCL = 201.4659

LCL = 86.92294

CL = 144.1944

The averages of each cell are plotted along with the control limits and the following is the chart



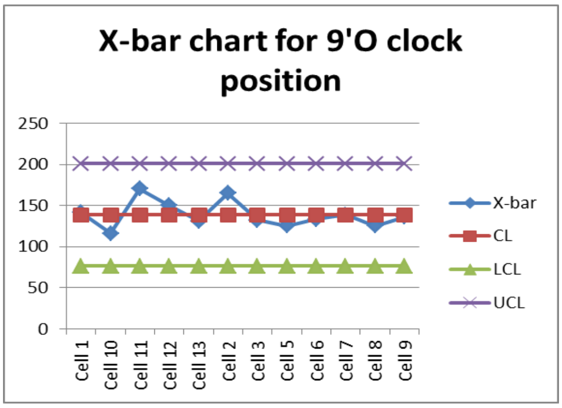
From the above chart we observe that all the averages (x-bar values) of the cells are falling within the control limits. This indicates that the process in control and the average thickness of the rings in all cells for the 6'O clock position are within the specified limits.

For 9'O Clock Position for a standard value of A2 = 1.287 from the standard table of control charts , the following are the control limits

UCL = 201.0213

LCL = 76.20373

CL = 138.6125



From the above chart we observe that all the averages (x-bar values) of the cells are falling within the control limits. This indicates that the process in control and the average thickness of the rings in all cells for the 9'O clock position are within the specified limits.

Similarly the range chart is constructed to check if there is any variability in the process of measurement.

The Range charts (R charts) are constructed for three positions 90 degrees(3'O clock position), 180 degrees(6'O clock position) and 270 degrees(9'O clock position)

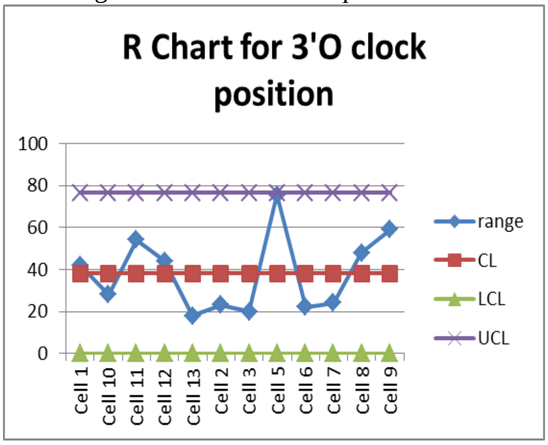
For 3'O Clock Position for a standard value of D3 = 0 and D4 = 2.004 from the standard table of control charts, the following are the control limits

UCL = 76.4025

LCL = 0

CL = 38.125

The Range chart for 3'O Clock position is



From the above chart we observe that all the range values of the cells are falling within the control limits. This indicates that the process in control and the variation of thickness of the rings in all cells for the 3'O clock position are within the specified limits. But we can observe that corresponding to cell 5 the range is touching the upper control limit. This indicates that the variation in this cell is much higher than the other cells. The variation in other cells is around the central line which is the average of the ranges. The variation in cells 2,3, 6,7 and 13 though they are limits can be checked once for thickness and check for any possibility of improving the variation.

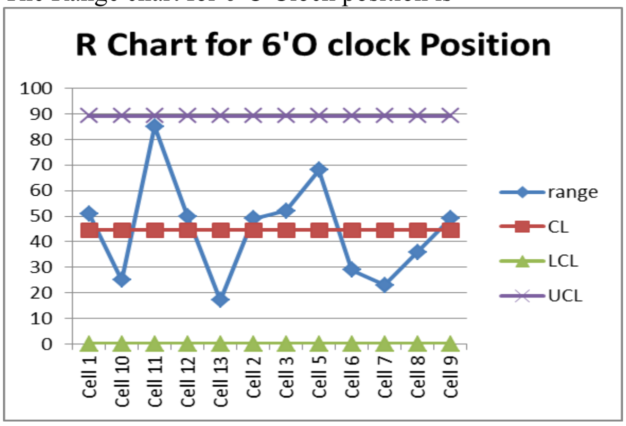
For 6'O Clock Position for a standard value of D3 = 0 and D4 = 2.004 from the standard table of control charts , the following are the control limits

UCL = 89.178

LCL = 0

CL = 44.5

The Range chart for 6'O Clock position is



From the above chart we observe that all the range values of the cells are falling within the control limits.

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This indicates that the process in control and the variation of thickness of the rings in all cells for the 6'O clock position are within the specified limits. But we can observe that corresponding to cell 11 the range is almost closer to the upper control limit. This indicates that the variation in this cell is much higher than the other cells. The variation in other cells is around the central line which is the average of the ranges. The variation in cell 7,10, 13 though they are limits can be checked once for thickness and check for any possibility of improving the variation.

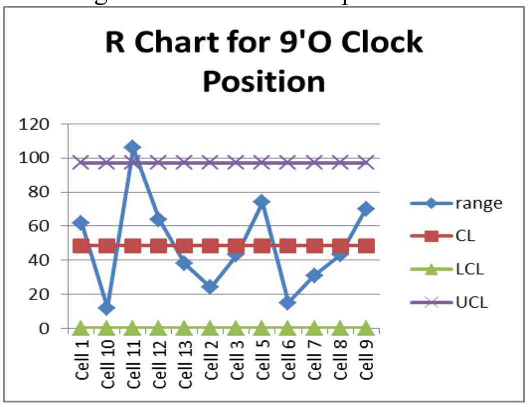
For 9'O Clock Position for a standard value of D3 = 0 and D4 = 2.004 from the standard table of control charts, the following are the control limits

UCL = 97.1773

LCL = 0

CL = 48.49167

The Range chart for 9'O Clock position is



From the above chart we observe that all the range values of the cells are not falling within the control limits. This indicates that the process in not in control and the variation of thickness of the rings in all cells for the 9'O clock position are not within the specified limits. Though the x-bar chart the averages are within the limits there is variation in the cell 11 which is beyond the control limits and can be considered as faulty. The thickness of this ring need to be checked again whether the variation is due to measurement or any other reason and is to be rectified if possible or replace. The reasons of this is to be analyzed. Further, except cell 3,8, 13which are closer to the central line the range values of other cells are very far from the central line which indicates that there is scope for improvement in the variation. ANOVA When only two samples are available, the t-test can be used to compare the means of the samples, which might be unreliable in the case of more than two samples. If only two means are compared, then the t-test (independent samples) will give the same results as the ANOVA (Fisher, 1935, Montgomery, Douglas C. (2001). It has been termed as one-way; as there is only one category whose effect has been studied ie thickness of chrome in this case. The purpose is to test whether the measurement of thickness in at the three different positions i.e at 3'O clock position, 6'O clock position and the 9'O clock position is significantly different or not. In order to test this, we use the hypothesis as H0: there is no significant difference in the thickness at all the three positions H1: there is significant difference in the thickness at all the three positions Since the average thickness of the three positions is taken into consideration we use the Analysis of Variance and use the F-test for variances as it is assumed that the average thickness is equal under Ho, the null hypothesis. If the measurement of thickness obtained at different positions turns out to be different, it would usually be concluded that the differences found are due to the differences in concentration of chromic acid and the current and temperature of chromic acid.

But this difference may also be the result of certain other factors such as outer diameter of the ring which can be attributed to chance, which is beyond human control. This factor is “error”.

Thus, estimates of the variation due to assignable causes (or variance between the samples) as well as due to chance causes (or variance within the samples) are obtained separately and compared using an F-test. The conclusions are drawn using the F - value or the p-value.

The test statistic in the case of one way Anova is

F = Between group variation/within group variation

Between group variation = Sum of squares of between group/degrees of freedom

Within group variation = Sum of squares of within groups/degrees of freedom

Degrees of Freedom: the number of degrees of freedom is the number of values in the final calculation of a statistic that are free to differ

The results of the ANOVA are as follows

Anova: Single Factor

SUMMARY (Table 1)

Groups Count Sum Average Variance

Column 1 12 1748.75 145.7292 93.27162

Column 2 12 1730.333 144.1944 115.0547

Column 3 12 1663.35 138.6125 258.0064

ANOVA(Table 2)

Source of Variation SS df MS F P-value F crit

Between Groups 336.6417 2 168.3208 1.082837 0.350362 3.284918

Within Groups 5129.66 33 155.4443

Total 5466.302 35

From Table 1 we can see the average of column1 which is 3'O clock position is more than column2 (6'O clock) or column 3(9'O clock) position. Further, the variation of column 1 is smaller than that of Column 2 or 3. In order to test the difference in means of three columns is significantly different or not we use the F test and Ho and H1given above.

Constant Variance is one of the assumptions in using Analysis of Variance (ANOVA). That is, the spread of residuals is roughly equal per treatment level. A common way to assess this assumption is plotting residuals versus fitted values. Recall that residuals are the observed values of your response of interest minus the predicted value of your response. In a one-way ANOVA, this is simply the observed values minus the treatment group mean. Dean and Voss (Design and Analysis of Experiments, 1999, page 112) suggest a rule of thumb to answer this question: if the ratio of the largest treatment variance estimate to the smallest treatment variance estimate does not exceed 3, s2max/s2min<3smax2/smin2<3, the assumption is probably satisfied

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Since p-value is > 0.05(α), and F value is < F critical value , we accept Ho and we conclude that there is no significant difference in the thickness at all the three positions and these differences occurring in the sample of table 1 is simply due to random sampling error.

The significance level α defines the sensitivity of the test. A value of α = 0.05 we inadvertently reject the null hypothesis 5% of the time when it is in fact true. In this situation we are 95% confident of accepting the null hypothesis with the data collected. The most commonly sued levels of significance are 0.1, 0.05 and 0.01.

IV. CONCLUSION

From the X –bar chart, all the averages (x-bar values) of the cells are falling within the control limits for all the positions. With this we can conclude that the process in control and the average thickness of the rings in all cells for the 3'O clock position, 6'O clock position and 9'O clock position are within the specified limits. This indicates that the process in control and the average thickness of the rings in all cells for the three positions.

From the Range Chart, the range values of the cells are falling within the control limits. This indicates that the process in control and the variation of thickness of the rings in all cells for the 3'O clock position and 6'O clock position are within the specified limits. The range values of the cells are not falling within the control limits. This indicates that the process in not in control and the variation of thickness of the rings in all cells for the 9'O clock position are not within the specified limits. Though the x-bar chart the averages are within the limits there is variation in the cell 11 which is beyond the control limits and can be considered as faulty. The thickness of this ring needs to be checked again whether the variation is due to measurement or any other reason and is to be rectified if possible or replace

X-bar chart for all the positions (Aggregate)

All the averages (x-bar values) of the cells are falling within the control limits for all the positions. This indicates that the process in control and the average thickness of the rings in all cells for the all positions together are within the specified limits. Further from ANOVA there is no significant difference in the thickness at all the three positions.

Practical implications

Chrome rings are widely used in dirt track engines because dirt does not stick to chrome and scour the cylinders. Hence a greater resistance for airborne contaminants can be achieved through chrome plating of piston ring and hence the necessity of maintaining the quality of thickness of the rings.

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