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Implementation of Statistical Quality Control Tools on Machining of Pipes

Prateek[1], Aadyansh Agarwala[2]
[1, 2]Department of Mechanical Engineering, Vellore Institute of Technology

***Abstract:** Inferior quality of pipes are most common and avoidable problem in the production unit. This often leads to increase in expenses precisely on variable costs such as raw materials. A lot of raw goods are wasted due to ignorance in quality management thereby increasing the cost of production. By implementing various quality control tools in this industry, we can reduce the inferiority in the pipes and hence reduce the cost.*

I. INTRODUCTION

Steel pipes are long tubes that are used for a spread of functions such as the transportation of fluids, automotive industry, manufacturing industry, etc. They are created in two innovative ways that lead to either a welded or seamless pipe. Seamless pipe tube is extruded and drawn from a billet while welded tube is produced from a strip that is roll formed and welded to produce a tube. Machining of pipes helps us to get the desired shape and dimensions which can be made ready for the industrial use. It majorly helps to reduce the diameter or cut the tube at various angles as per requirement. In machining of welded or seamless pipes, there are various defects found such as, poor surface finish, variation in thickness on weld line, due to chatter error, tool misalignment, or burning of material. This is an important issue that needs to be addressed. In this paper, we implement several SQC (statistical quality control) tools to reduce the variation of diameter of pipes resulting in better quality. In industry, rod or cylinder product is an important product. Many products want high accuracy of roundness. The examples rod uses in industrial are automotive production, machine production and medical product production. Surface roundness plays an important role on the required tolerance and fit especially during part assembly. Optimization parameters of machine to make good quality for surface roundness are of great concern in manufacturing environments, where economic of machining operation plays a key role in competitiveness in the market. The optimization parameters can produce maximize production rate. The traditional methods have lower accuracy and production rate. Therefore, to improve on productivity and reduce cost new methods are being implemented.

II. OBJECTIVE

There are many researches regarding the machining of pipes, its manufacturing and quality control. The machining and its theory are the core part of mechanics. So, the objective of this research paper is to study SQC tools and implement a particular manufacturing process of machining of Pipes, and focusing on the level of performances by various SQC tools that help us to find which manufacturing process is much efficient.

III. METHODOLOGY

The machine adopted the steel pipe fixed, double symmetric rotating cutting scheme. While the process of rotary cutting, the blades acted as role of mutual support, which ensured that the cutting section was absolutely vertical without buzz. The feed movement and the main transmission were realized by the eccentric gears fixed on the planet gears and the planet gears meshing with the sun gear respectively. At the same time, the device adopted the process of automatic feeding to guarantee completely cutting.

A. Motion Principle of Cutting Method

The main function of the planet type tube cutting tool is to complete the cutting workpiece of various dimensions, and accomplish continuous cutting. The pipe cutting machine mainly consists of feeding device, clamping device, cooling device and cutting head device. The cutting motion of the pipe cutting machine mainly includes these two sections:

1) *Main movement:* It causes the cutting edge of the tool and the surface of its adjacent tool to cut extra material onto the workpiece and transform it into cutting, which forming a new surface of the workpiece.
2) *Feed Movement:* It is an additional relative movement between the tool and the workpiece.

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As shown in Fig. 1, the tools cut through the steel pipe firstly, and then rotated around the steel pipe to cut it through by rolling the walls of pipes.

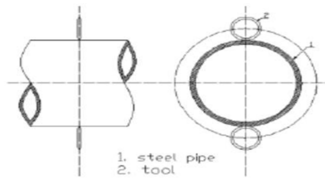


Fig. 1. Cutting principle of pipe cutting machine.

B. Calculation Of Rotational Velocity Of Cutting Tool

Let us assume:

Number of teeth of gear A = T_a = *40*

Number of teeth of gear D = T_d = *90*

Let, d_a , d_b , d_c , d_d *be the pitch circle diameter of gear A, B, C and D respectively.*

So, we have, $d_a + d_b + d_c = d_d$

Or, $d_a + 2\,d_b = d_d$

And also, $T_a + 2\,T_b = T_d$

Or, $40 + 2\,T_b = 90$

Or, $T_b = T_c = 25$

Also, we know that, Gear ratio = $\frac{\text{rotation of driver gear}}{\text{rotation of driven gear}}$

And, Gear ratio = $\frac{\text{teeth of driver gear}}{\text{teeth of driven gear}}$

Both of these conclude into: $\frac{\text{teeth of driver gear}}{\text{teeth of driven gear}} = \frac{\text{rotation of driver gear}}{\text{rotation of driven gear}}$

Table 1. Calculation of revolution of gears

Step	Conditions of motion	Revolutions of Arm	Revolutions of Gear A	Revolutions of Gear B-C	Revolutions of Gear D
1.	Arm fixed; gear A rotates one revolution clockwise	0	-1	$+\frac{T_a}{T_b}$	$+\frac{T_a}{T_b}\cdot\frac{T_b}{T_d}=\frac{T_a}{T_d}$
2.	Arm fixed; gear A rotates through x revolutions	0	-x	$+x\cdot\frac{T_a}{T_b}$	$x\cdot\frac{T_a}{T_d}$
3.	Adding -y revolutions to all elements	-y	-y	-y	-y
4.	Total motion	-y	-x-y	$(x\cdot\frac{T_a}{T_b}) - y$	$(x\cdot\frac{T_a}{T_d}) - y$

Now, since gear A makes 1 revolution clockwise, so,
-x-y = -1
Or, x+y= 1

And, since gear D is stationary,

$$(x \cdot \frac{T_a}{T_d}) - y = 0$$

$$\text{Or, } x \cdot \frac{40}{90} - y = 0$$

$$\text{Or, } 40x - 90y = 0$$

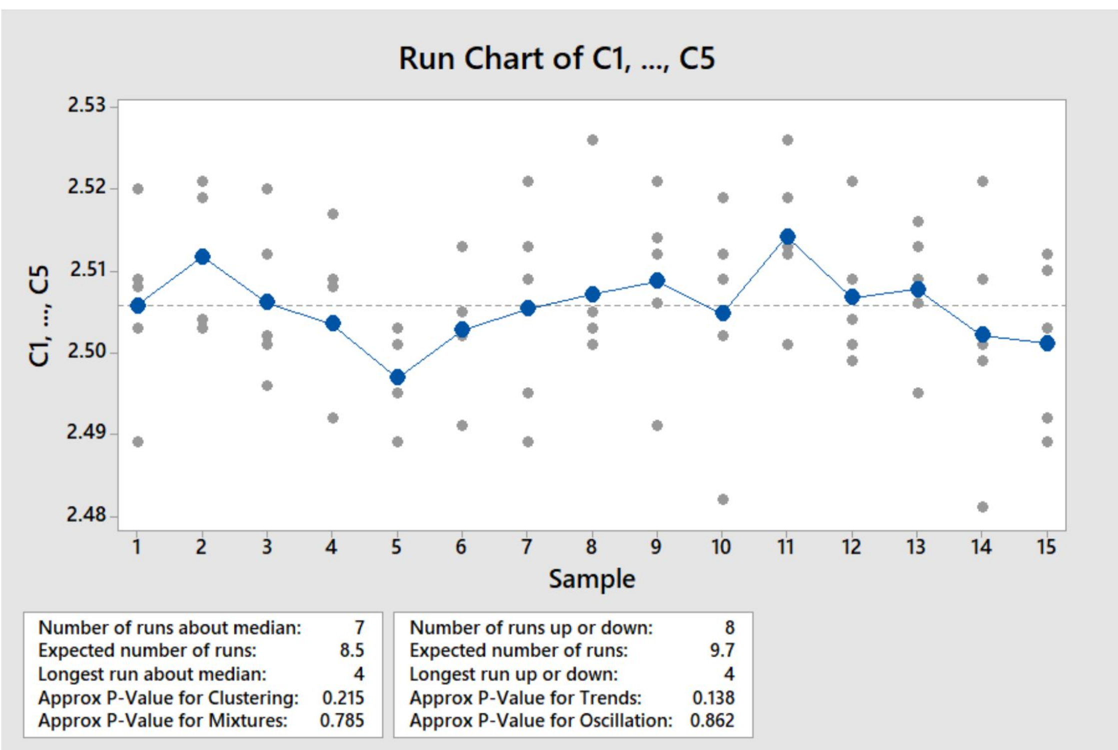
From these results, we conclude that x = 0.692 and y = 0.308
Therefore, Speed of arm = -y = 0.308 revolutions clockwise
Assuming the motor provides 100 rpm to hollow shaft which transfers to sun gear. Therefore the number of gear teeth per minute is 40 X 100 = 4000.

$$\frac{T_a}{T_b} = \frac{40}{25} = 1.6$$

So, number of rotations of gear B per minute = 1.6 X 100 = 160 rotations
Since the cutting tool is attached to the planetary gear through eccentric gear, therefore the tool will be rotating and cutting at 160 rpm.

C. Statistical Quality Control Tools

1) *RUN CHART:* A run chart is a line graph of data plotted over time intervals. By collecting and charting data over time, we are finding trends and patterns in the process. They show us how the process is running. The run chart is a valuable tool at the beginning of the project, as it provides important information about the process before we have collected enough data to create reliable control limits.



Graph 1. Run Chart

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2) *Control Charts:* The x-bar and R-chart are quality control charts are used to monitor the mean and variation of a process based on samples taken in a given time. The control limits on the charts are used to monitor the mean and variation of the process going ahead. If a point is out of the control limits, it shows that the mean or variation of the process is out-of-control; assignable causes may be suspected at this point. It is also employed to monitor the effects of process improvement theories. This is the data taken of the outer diameter of the pipes after we are done with machining in cm (centimeters).

↓	C1	C2	C3	C4	C5
1	2.509	2.489	2.508	2.520	2.503
2	2.512	2.503	2.521	2.504	2.519
3	2.501	2.502	2.520	2.496	2.512
4	2.509	2.492	2.492	2.508	2.517
5	2.495	2.497	2.489	2.501	2.503
6	2.513	2.491	2.502	2.503	2.505
7	2.521	2.495	2.513	2.489	2.509
8	2.503	2.501	2.505	2.526	2.501
9	2.512	2.491	2.506	2.514	2.521
10	2.482	2.509	2.519	2.512	2.502
11	2.501	2.513	2.526	2.512	2.519
12	2.521	2.509	2.499	2.501	2.504
13	2.495	2.513	2.509	2.516	2.506
14	2.499	2.509	2.501	2.521	2.481
15	2.510	2.492	2.503	2.512	2.489

Table 1. Data of outer diameter of pipes

We know that Mean = Average = $\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$

And, Range = R = maximum value – minimum value

Also, Standard Deviation = $\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$

On solving the given data by using the formulas we can get the following table:

↓	C1	C2	C3	C4	C5	C6	C7	C8
						Mean	Standard Deviation	Range
1	2.509	2.489	2.508	2.520	2.503	2.5058	0.01130	0.031
2	2.512	2.503	2.521	2.504	2.519	2.5118	0.00829	0.018
3	2.501	2.502	2.520	2.496	2.512	2.5062	0.00965	0.024
4	2.509	2.492	2.492	2.508	2.517	2.5036	0.01110	0.025
5	2.495	2.497	2.489	2.501	2.503	2.4970	0.00548	0.014
6	2.513	2.491	2.502	2.503	2.505	2.5028	0.00789	0.022
7	2.521	2.495	2.513	2.489	2.509	2.5054	0.01310	0.032
8	2.503	2.501	2.505	2.526	2.501	2.5072	0.01060	0.025
9	2.512	2.491	2.506	2.514	2.521	2.5088	0.01130	0.030
10	2.482	2.509	2.519	2.512	2.502	2.5048	0.01410	0.037
11	2.501	2.513	2.526	2.512	2.519	2.5142	0.00926	0.025
12	2.521	2.509	2.499	2.501	2.504	2.5068	0.00879	0.022
13	2.495	2.513	2.509	2.516	2.506	2.5078	0.00811	0.021
14	2.499	2.509	2.501	2.521	2.481	2.5022	0.01470	0.040
15	2.510	2.492	2.503	2.512	2.489	2.5012	0.01040	0.023

Table 2. Calculation of Mean, Standard Deviation and Range

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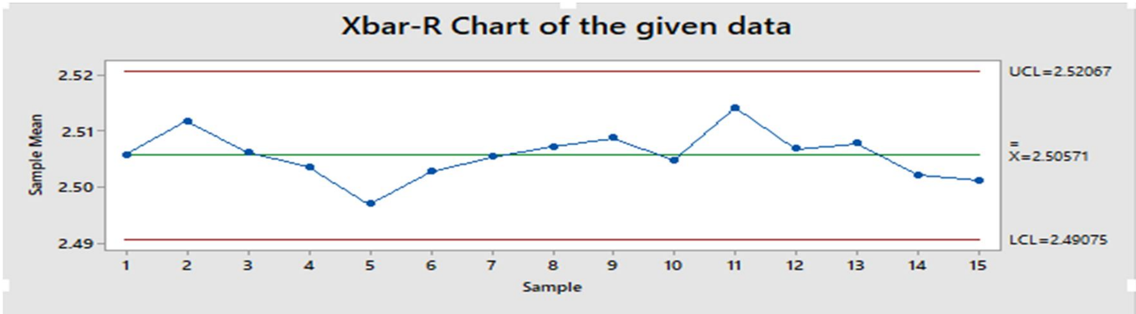
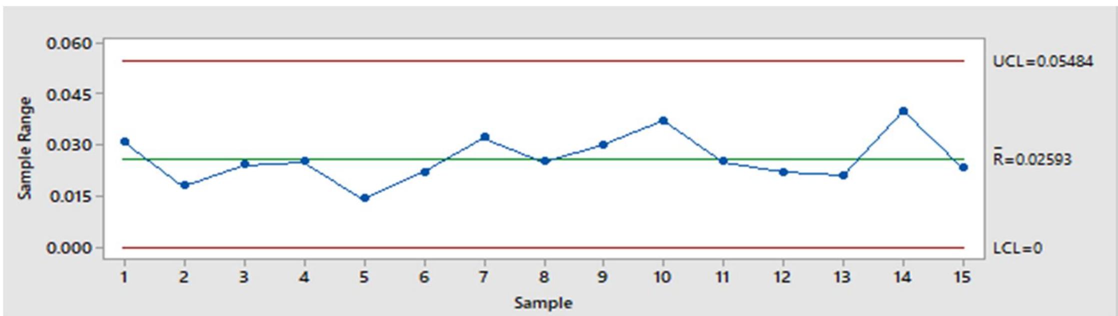
On drawing the X bar – R chart we get:



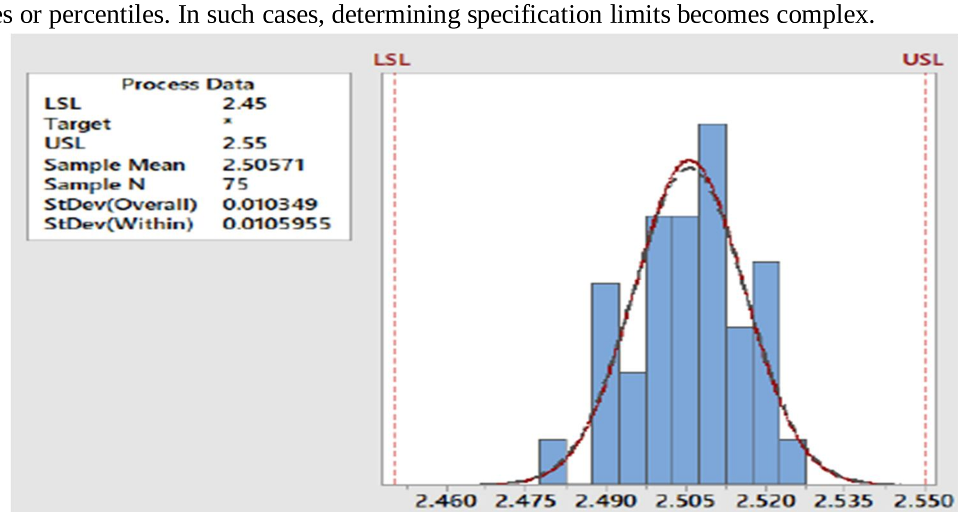
Graph 1. Xbar Chart of the given data



Graph 2. R Chart of the given data

On the x-bar chart, the y-axis shows the grand mean and the control limits while the x-axis shows the sample group.
On the R-chart, the y-axis shows the range grand mean and the control limits, while the x- axis shows the sample group.
The UCL and LCL for x bar chart is 2.52067 and 2.49075 respectively. The UCL AND LCL for R bar chart are 0.05484 and 0 respectively.

3) *Process Capability:* The process capability is a measurable property of a process to the specification, expressed as a process capability index (e.g., Cpk or Cpm). The output of this measurement is usually illustrated by a histogram and calculations that predict how many parts will be produced out of specification (OOS). The most interesting values relate to the probability of data occurring outside of customer specifications. These are data appearing below the lower specification limit (LSL) or above the upper specification limit (USL). An ordinary mistake lies in using capability studies to deal with categorical data, turning the data into rates or percentiles. In such cases, determining specification limits becomes complex.



Graph 3. Process Capability Graph

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Cp (process capability ratio) : $C_p = \dfrac{\text{Upper specification - Lower specification}}{6\sigma} = \dfrac{\text{USL- LSL}}{6\sigma}$

Where, C_p – Capability Index, σ – Population standard deviation, 6σ – Capability index
If Cp > 1 , this means that the process variation is less than the specification.
If Cp < 1, this means that the process variation is not capable of meeting the required specification.
If Cp = 1 , this means that the process is just meeting the specifications. Therefore greater the Cp , better is the quality .

Cpk (Process capability index)-

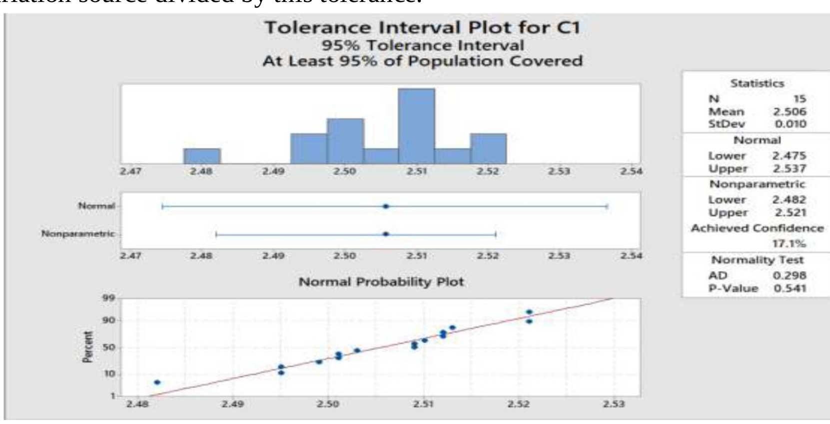
$$Cpk = \text{Minimum of } \frac{USL - \bar{X}}{3\sigma} \text{ or } \frac{\bar{X} - LSL}{3\sigma}$$

Where,

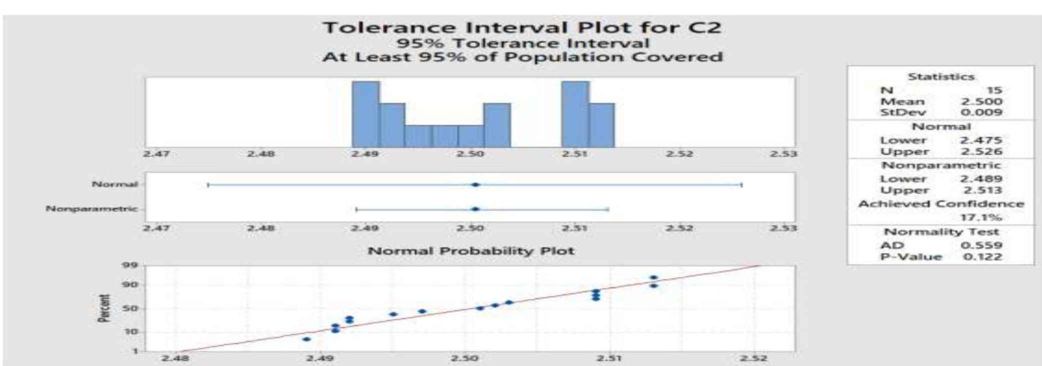
USL – Upper Specification limit
LSL – Lower Specification limit
σ – Sigma (Process)
$\bar{X}$ – process average

So, we get,
Cp = (2.55 - 2.45) / (2.52 - 2.49) = 3.33
Cpk = min (((2.55 - 2.51)/ 0.015) , ((2.51 - 2.45) / 0.015)) = 2.667
Therefore, the process variation is less than the specification limit. Hence the process is capable.

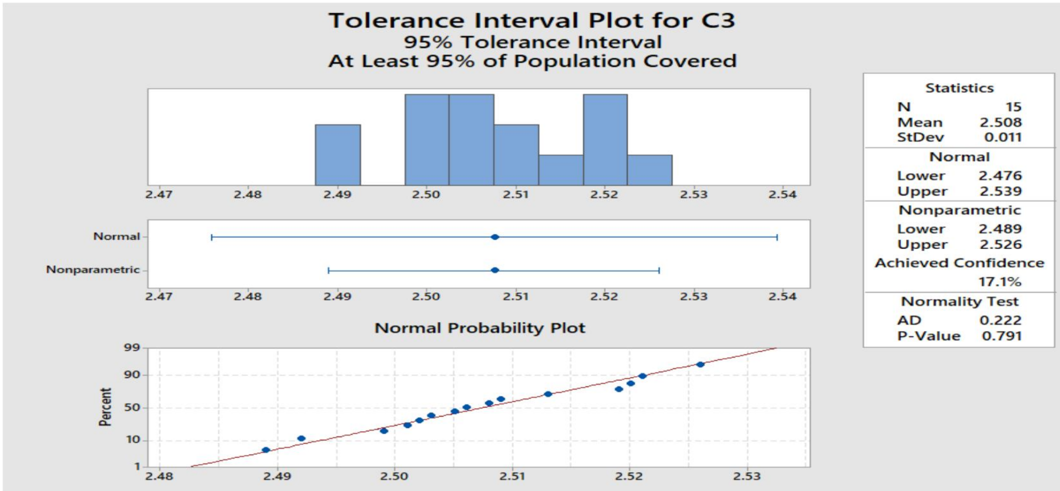
4) *Tolerance:* One of the statistics that is directly affected by specification limits is the %tolerance statistic, which compares the tolerance with the study variation. Ideally, the tolerance should amply encompass the study variation, making sure the variability due to Gage R&R and part-to-part variation do not push the process output beyond the specification limits. When a process has two specification limits, the tolerance is equal to the difference between them, and %Tolerance is equal to the study variation of a given variation source divided by this tolerance.



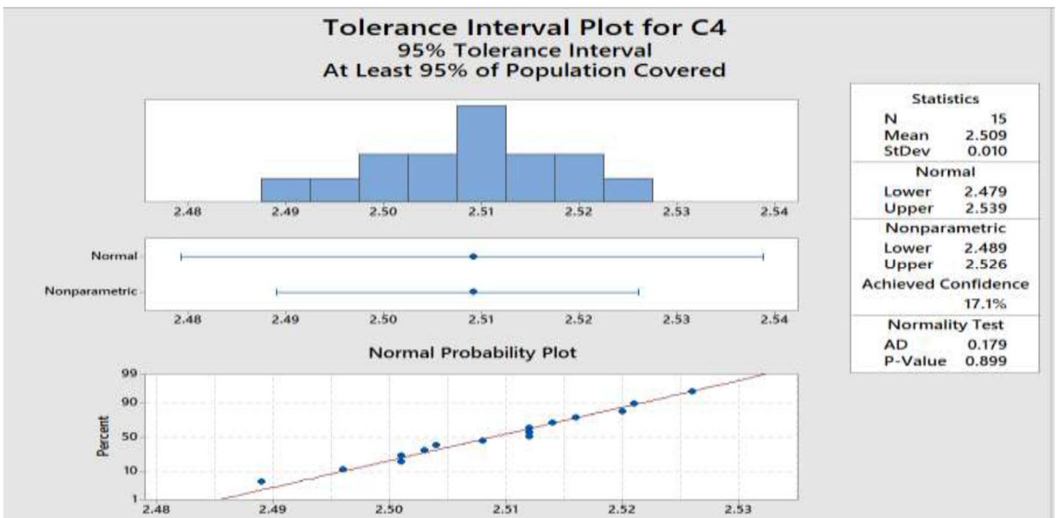
Graph 4. Tolerance Interval for Plot –



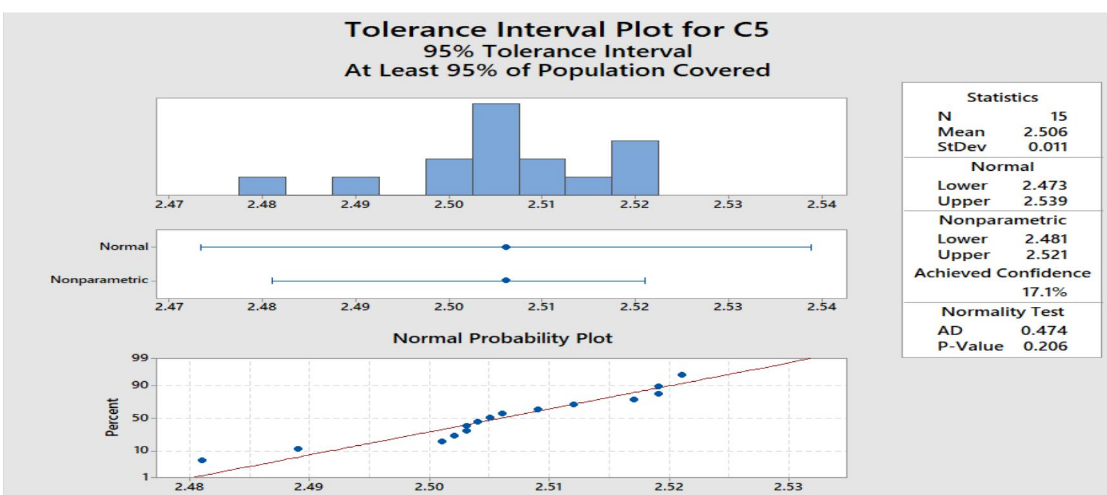
Graph 5. Tolerance Interval for Plot -2



Graph 6. Tolerance Interval for Plot -3



Graph 7. Tolerance Interval for Plot -4



Graph 8. Tolerance Interval for Plot -5

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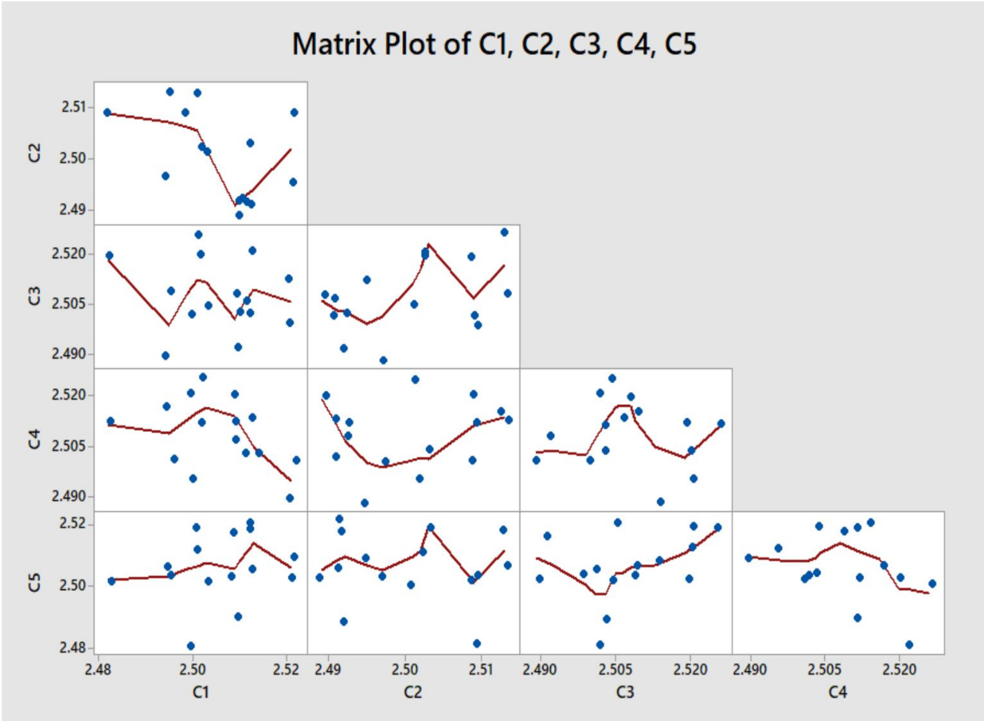
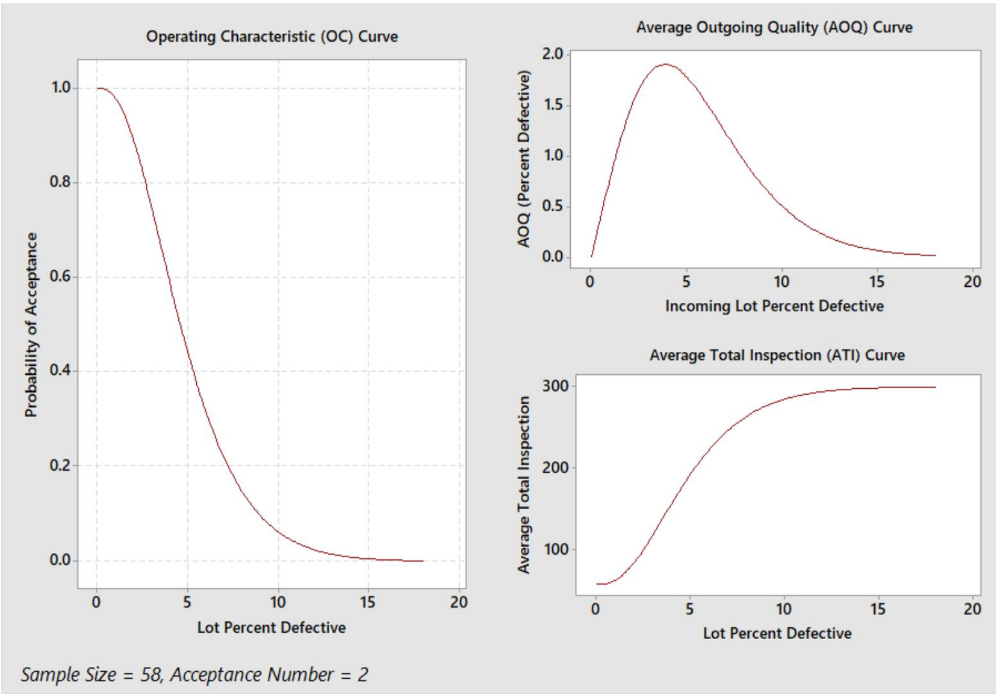
5) *Scatter Diagram:* This is a type of matrix plot that can accept up to 20 variables and creates a plot for every possible combination. This matrix of plots is effective because we have multiple variables and we would like to see relationships among pairs of variables.



Graph 10. Scatter Diagram

6) *OC (Operating Characterstics Curve):* The operating characteristic (OC) curve represents the discriminatory power of an acceptance sampling plan. The OC curve plots the graph between the probabilities of accepting a lot versus the fraction of defective. We have examined the OC curve before using a sampling plan.



Graph 11. OC Curve

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7) *CUSUM (Cumulative Sum):* A cumulative sum (CUSUM) chart is a kind of control chart that is used to monitor small shifts in the process mean. It uses the cumulative sum of deviations from target. It plots the cumulative sum of deviations from the target for individual measurements or subgroup means. It requires two parameters, the first being, a reference value (k) specified in sigma units and the other, the decision limit (h) specified in sigma units.

	Mean	upper cusu	lower cusu	Ci- for chart			
s.no.	xbar	Ci+	Ci-	Ci-	Y=0	Y=+H	Y=-H
1	2.5058	0.0003	0	0	0	0.025	-0.025
2	2.5118	0.0066	0	0	0	0.025	-0.025
3	2.5062	0.0073	0	0	0	0.025	-0.025
4	2.5036	0.0054	0.0009	-0.0009	0	0.025	-0.025
5	2.497	0	0.0084	-0.0084	0	0.025	-0.025
6	2.5028	0	0.0101	-0.0101	0	0.025	-0.025
7	2.5054	0	0.0092	-0.0092	0	0.025	-0.025
8	2.5072	0.0017	0.0065	-0.0065	0	0.025	-0.025
9	2.5088	0.005	0.0022	-0.0022	0	0.025	-0.025
10	2.5048	0.0043	0.0019	-0.0019	0	0.025	-0.025
11	2.5142	0.013	0	0	0	0.025	-0.025
12	2.5068	0.0143	0	0	0	0.025	-0.025
13	2.5078	0.0166	0	0	0	0.025	-0.025
14	2.5022	0.0133	0.0023	-0.0023	0	0.025	-0.025
15	2.5012	0.009	0.0056	-0.0056	0	0.025	-0.025

Table 4. CUSUM Values Table

Mu0	2.505
sigma	0.005
shift	0.001
Mu1	2.506
K	0.0005
H	0.025

$C_i^+ = \max\{0, x_i - (\mu_0 + K) + C_{i-1}^+\}$ -→ UPPER CUSUM

$C_i^- = \max\{0, (\mu_0 - K) - x_i + C_{i-1}^-\}$ -→ LOWER CUSUM

Where μ_0 is the Target Value, x_i is the average value of ith sample also μ_1 is the Shifted value of mean or Characteristic so that $\mu_1 = \mu_0 + \delta\sigma_x$. Also, $C_0^+ = C_0^- = 0$

$K = \frac{|\mu_1 - \mu_0|}{2} = \frac{\delta\sigma_x}{2}$ -→ Reference value

$H = 5\sigma_x$ -→ Decision Interval

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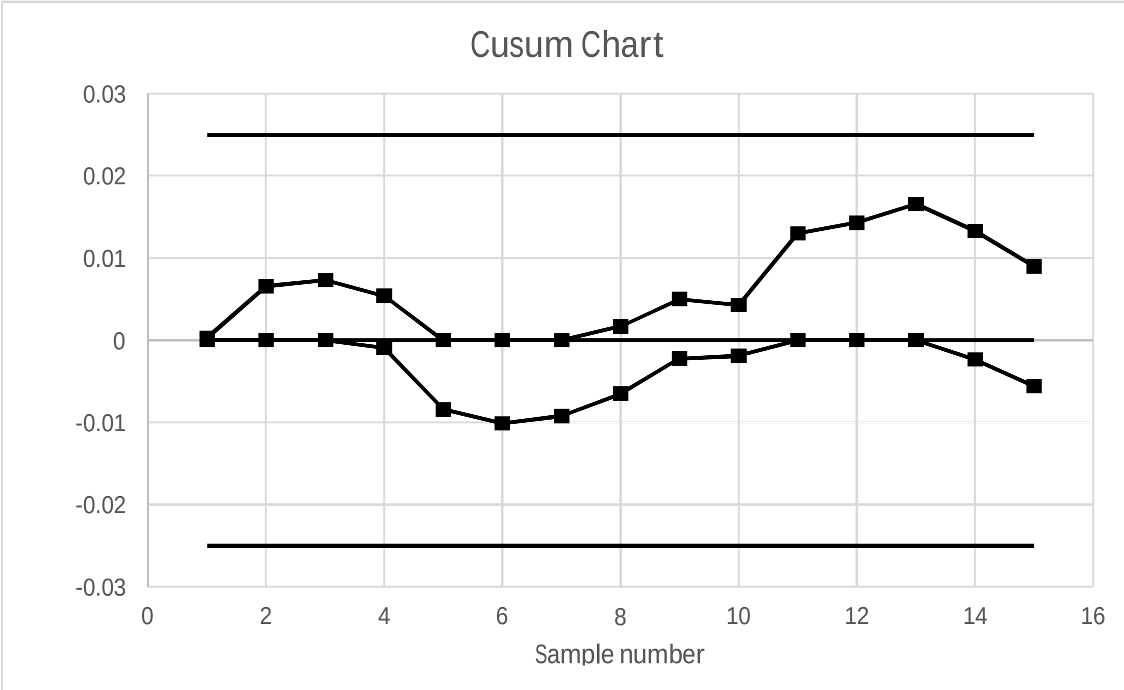
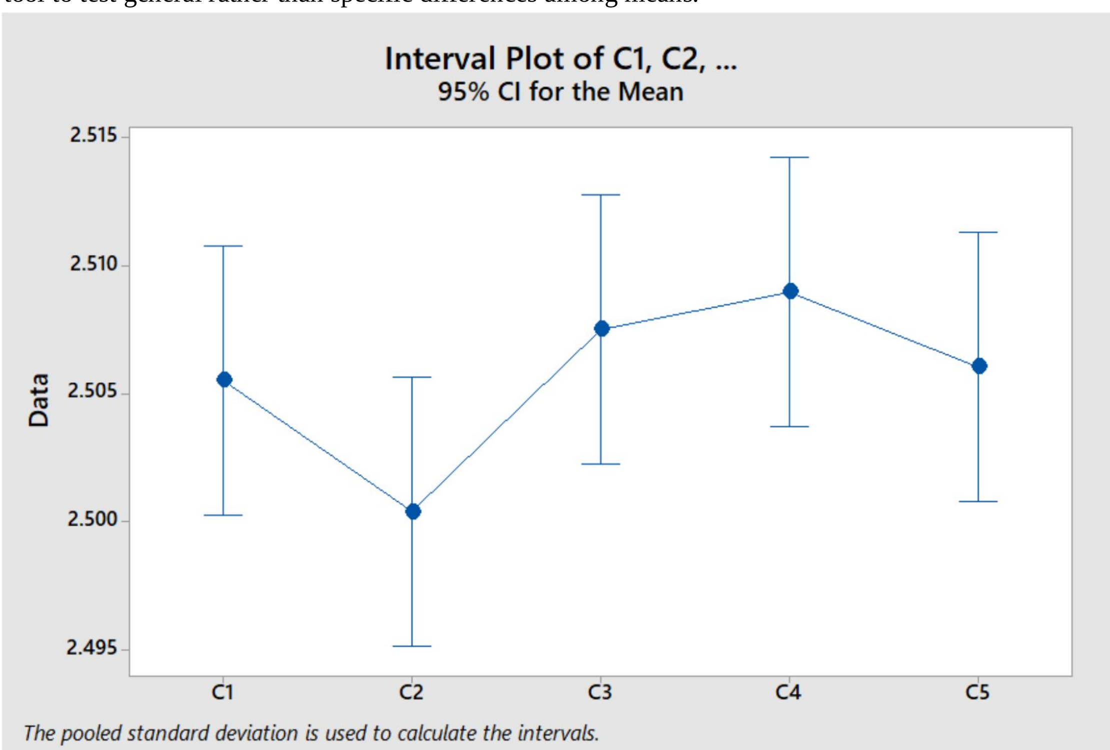


Graph 12. CUSUM Chart

8) *ANOVA (Analysis Of Variance):* Analysis of Variance (ANOVA) is a statistical method that is used to test differences between two or more means.

It is used as a tool to test general rather than specific differences among means.



Graph 13. ANOVA Chart

9) *Fishbone Diagram:* Based on the picture, we can conclude that the disability can be caused by humans, machines, materials and the methods used. So, improvements can be made to these four aspects.

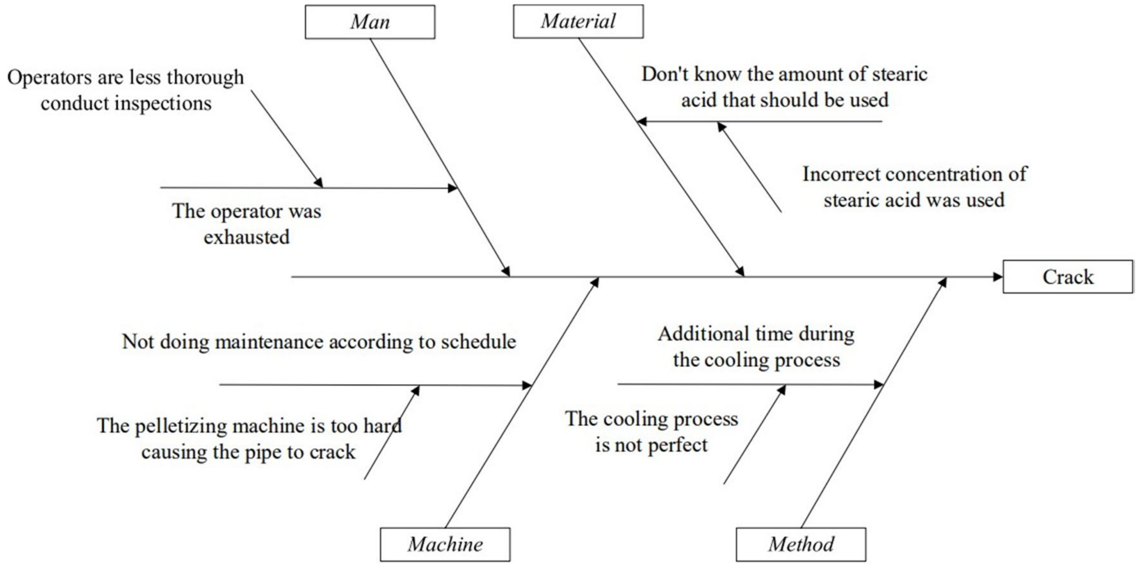


Fig. 2. Fishbone Diagram

IV. RESULTS

Using the quality control tools we can infer various results from different parameters. The UCL and LCL for x bar chart is 2.52067 and 2.49075 respectively. The UCL and LCL for R bar chart are 0.05484 and 0 respectively. The process capability ratio of the given data is 3.33 and process capability index is 2.667 which concludes that since process is within specification limit, the process is capable. From a very precise quality control tool the CUSUM chart we can infer that since no value is exceeding the control limits , the process is under control .

V. CONCLUSION

The main purpose of this study it to provide working mechanism of machining in pipes; and study different SQC tools that used to make manufacturing effective. The data showed many flaws in the machining. The X bar and R bar chart showed that there weren't any products that were out of control but after studying the scatter diagram, it can be seen that the processes were not fully in control as there were flaws arising in machining section and casting section. Thus, it is was necessary to reduce the rework due to defects in casting and machining section and to improve the quality of product. The flaws were classified by Fish bone Diagram. Productivity can be increased by applying Statistical Quality control.

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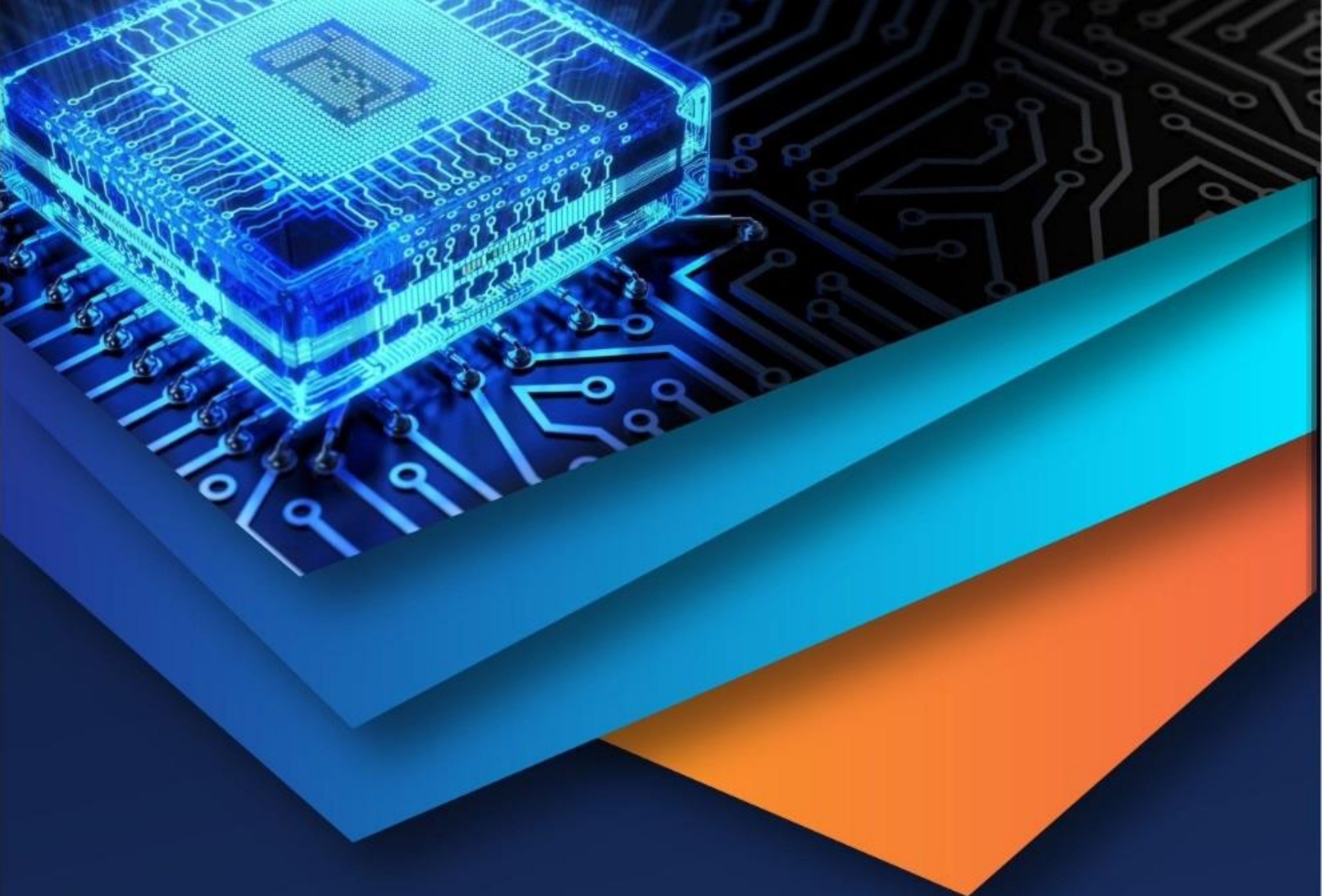

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