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Application of Six Sigma Methodology to Improve Design of Feeding Mechanism

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Abstract: ***The researchers investigated the role of six sigma methodology in improving the design of feeding machine used mainly in food dairy industries. The current sigma level is studied and is improved also. The machine has been designed using CREO Software it contains a hopper, a house and a piston cylinder arrangement assisted by more than two nozzles (number of nozzles can be changed according specific requirement). The whole mechanism is made up of stainless-steel grade 304 which is favorable for food and pharma industry. The machine can be used for cup filling, bottle filling and similar kind of operation. Authors observed that the new sigma level increased critically. Material selection and standardization was done according to International Organization for Standardization (ISO) norms. The results obtained were favorable for most of the times about 7 to 12% tolerances were observed.***

Keywords: Piston cylinder arrangement, Six Sigma methodology, Nozzle, Quality control

I. INTRODUCTION

Now a day's world becoming faster and so as the concept of batch production. New advancements are being done on daily basis hence we were abided to come up with something new idea which must be unique and serve the purpose of current batch production system along with withdrawing difficulties faced in existing system.

In the pursuit of design improvement, the most important thing is to ensuring in minimizing the design complication and also to maintain the required standards with proper quality control. For the machine which we have designed, in past many designs were made but they fell short of expectations in the design there were one or more than one loop holes. So, keeping in mind all the things we were supposed to design a machine which should make the expectations and nullifying the loop holes of previous designs also maintaining the prescribed quality standards.

In the food and dairy industry mainly in the section where the process contains pieces, the quantity as well as quality is the most tiresome thing to deal with. Currently in the industry the rotary motion is used which in turn is provided by linear motion so, the energy losses are there. The granules (pieces) which are to be dispensed are being stuck in the annular space in nozzles. The most important thing in the granules is their uniformity but currently the uniform size is not provided.

To achieve its end measurements and prescribed standards, the process requires several steps on the grounds of six sigma (DMAIC approach):

1) Defining the problem and development of six sigma principle
2) Measuring the quantitative data
3) Analyzing and simulation of data
4) Identifying the proper method to control the process
5) Controlling the improvement and working for its betterment

A. Background of Six Sigma Principle

Recently many industries have started implementing this principle to achieve customer satisfaction. It is defined as customer centric process-based data driven break through business improvement strategy. Customer is at the center of this principle. Until and unless anything is measured, it cannot be improved. So, data is the most important thing in this approach. By improving the above written three aspects quality is also going to be improved so, if the quality is good the product will better serve the purpose for which it is made and finally the business is also going to be improved. The DMAIC approach is shown below.

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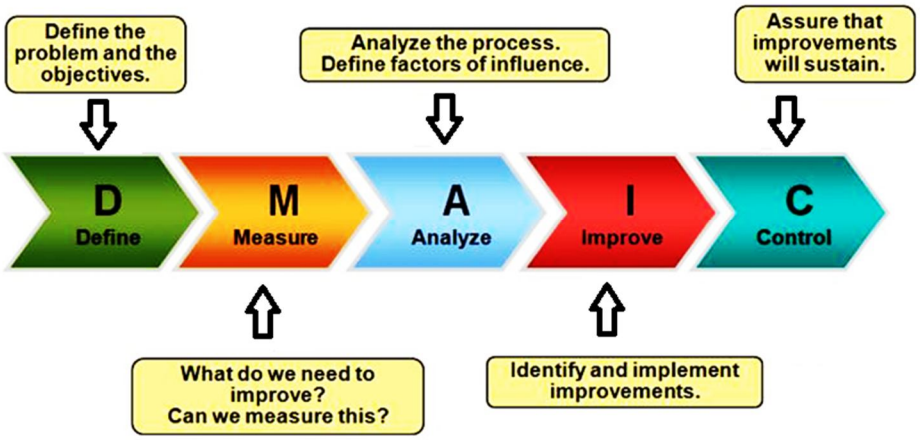

Figure-1: DMAIC Roadmap

II. LITERATURE REVIEW

The most tedious process any research or project is review of past in which similar kind of thing has been done. The authors found out three-four patents and four-five research papers assisting our research. The first research paper referred (Kothalkar and Modak 2013), which deals about the degree of nozzle at which the maximum flow rate occurs. Next, authors reviewed two patents (1. US3656518, 2. US8118068B2) and studied the design of machine and the mechanism to be used. Throught a Malaysian research paper, authors got to know about fish feeding mechanism to dispense the granules. Another research paper (Chianrabutra, Mellor and Yang) made us aware about next generation additive manufacturing system. For a piston cylinder we referred (Rihong and Qungui, South China University of Technology) from it the benefits of pneumatic cylinder were known. For the cushioning in the cylinder we referred (Lai, Liang, Li, Wu and Liu 2016). About position control pneumatic cylinder working on PLC, the information on it was obtained from conference paper jointly held by IEEE/ASME (Gyeviki, Sarosi, Csikos 2011).The mechanism of design was inspired from a design Flexible Automated Bottle Filling Machine which was according to guide line proposed by mechatronic systems design (Powell Mlambo, Trymore Mambumba, Nyasha Bhogodho 2017). How to use Six Sigma approach was a hefty task but our guide suggested us few researches from which we could know how to culminate Six Sigma in our research. Also, how to reduce manufacturing cost in food industry through Six Sigma was also explained in one of the research paper given by our guide (Hsiang- Chin Hung, Ming-Hsien Sung 2011) (Ismail Idrissi, Abdelhalem Mesfioui, Bouchra Benazzouz 2016) (Benny Tjahjono, Peter Ball 2010) (Virendera Narula, Sandeep Grover 2015).We also consulted with FESTO to see which cylinder suits our design and fulfill our requirements of pressure and stroke length. From a visit to a local engineering workshop named PANCHAL Engineering, authors got the idea of type of nozzle and cup filling process. MINITab-16 software helped us in preparing graphs and charts for our research paper.

A. Define Phase

Our main objective was to apply Six Sigma methodology to improve feeding mechanism and to reduce the losses by at least 50% from the existing one. As flaws are discussed in introduction the problem statement was being made as “Application of Six Sigma Methodology to Improve Design of Feeding Mechanism”. Our main focus was to understand the designing software and the six-sigma principle in its proper format. Starting from point zero that is the understanding and getting knowledge of designing software was the main hectic task because we were having choices like CREO, AutoCAD, Solid works, ANSYS and many more. Authors also learned MINITAB-16 software for studying current six sigma level and to know improvement.

B. Measure

Until and unless anything is measured, it cannot be improved. So, data is the most important thing in this approach. So, to know the current sigma level of operation we measured mass of granules dispensed by the currently used machines. There was a batch production everyday so, we took readings for different batches on different days.

Due to mass production every product cannot be measured, hence random samples were studied (i.e. variable data) throughout the day. Sample size is ten. We repeated this process of measurement for different batches during five days with ten different cans.

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Table-1: Weight in can (Existing case)

Subgroup	Weight in can (Gram)									
	1	2	3	4	5	6	7	8	9	10
1	1	1.5	2	0.5	3.5	2	3	1.5	1	1
2	2.5	2.5	3.5	0.5	1	1.5	2	0.5	1.5	2.5
3	5	4.5	3	2	1.5	0.5	1	2.5	1.5	1
4	0	1.5	0	0.5	0	1	1	2	3	3.5
5	2.5	2	2	2	1.5	2	1	1.5	1	2.5

Figure-2: Current feeding machine


Figure-3: Feeding Mechanism

C. Analyze

Once the measurement is taken the next step of DMAIC methodology is to analyze the data. As our data type is variable type, control charts are better tool for analysis. To plot the control charts, we use Minitab software. Following charts shows X-bar chart, R chart, Histogram for recorded data. In addition to that by doing brain storming we also drawn Fishbone (i.e. Cause and Effect) diagram and Pareto chart.

As it can be observed from the Histogram, most of the readings are out of specification limits. The lower specification limit (LSL) is 1gm and upper specification limit (USL) is 1.5gm. Also, this analysis shows value of Process capability (Cp) 0.08 and Defect per million opportunity (DPMO) is 838470.35.

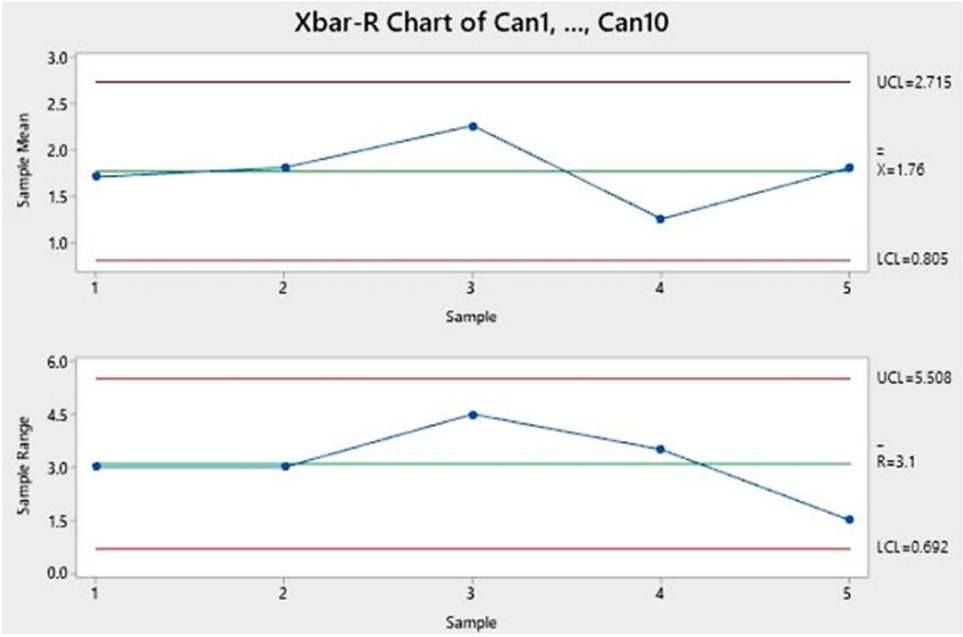

Figure-4: X-bar and R Chart

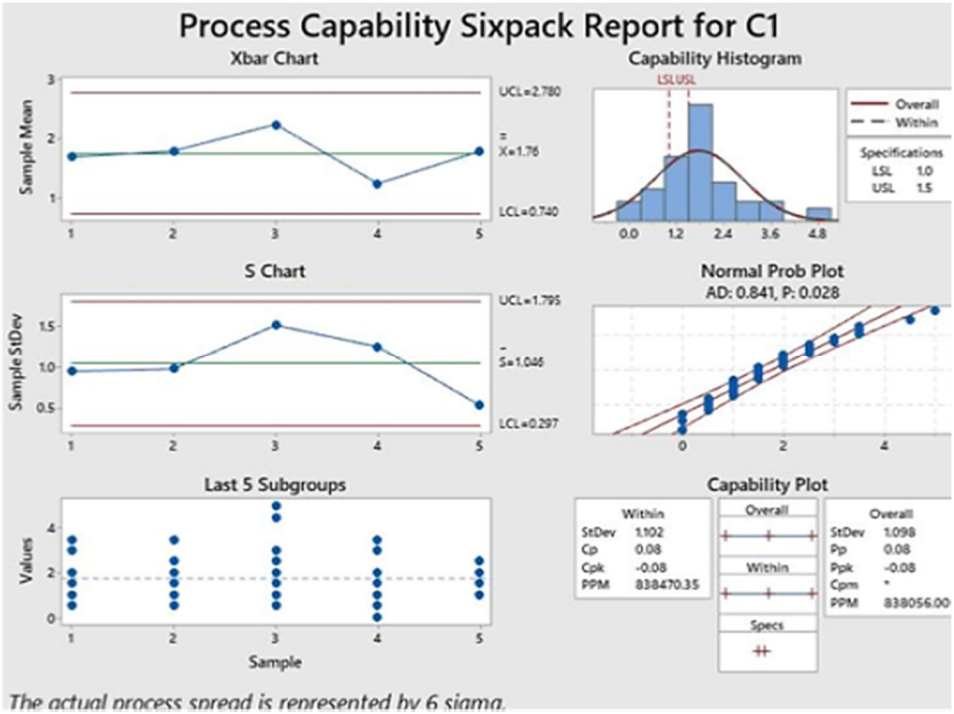

Figure-5: Sixpack Analysis

Table-2: Sigma and DPMO Level

Sigma	Yield (%)	DPMO
0.4	14	860000
0.5	16	840000
0.6	19	810000

Now comparing DPMO with above table our current sigma level is 0.5.

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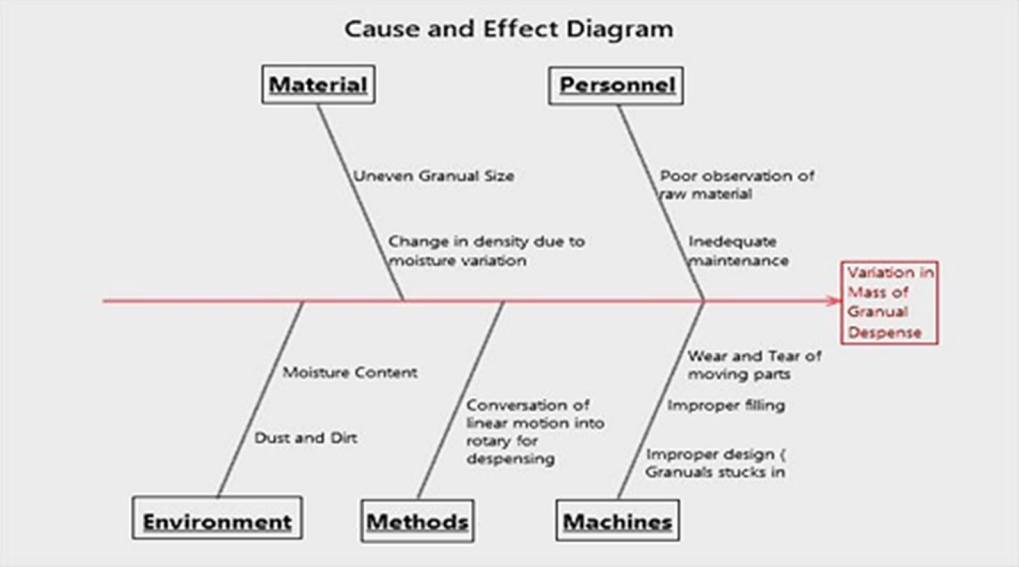

Figure-6: Cause and Effect Diagram for variation

To identify all possible causes responsible for failure, brainstorming is done. Cause and effect diagram is shown above represents all these possible cause.

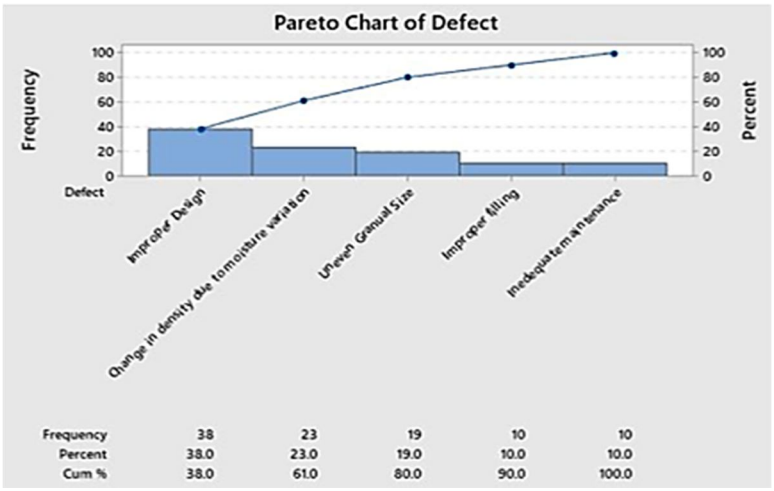

Figure-7: Pareto Diagram

After analyzing pareto diagram, we got to know that improper design was the major contributing factor leading to defect and also change in the density due to moisture content; was also a contributing factor.

D. Improve

In improve phase we decided to go with concurrent engineering technique i.e. doing two different things simultaneously. As discuss in the title we are designing and also applying six sigma methodology, so these two tasks has to be performed together. As can be seen from pareto diagram, improper design and uneven granule size are the factor contributing to major failure. The uneven granule size cannot be cured at the filling stage so, the supplier is responsible for this. Now the only parameter remains to be improved is to do better design.

To improve the existing design, we analyze the problem in current design. After discussing with the operator and workers involved, we came to know that stuck of granule in gap between casing and dispensing element leads to variation in mass of granule dispensed. Besides, we observed that there is transmission loss when reciprocating motion of piston is converted into rotary motion of dispensing element. To overcome the stated causes, we searched for many designs and visited industry involved in manufacturing of such kind of machines.

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At the end of our research we came up with cup filling mechanism for our problem. The design which we are proposing is constituted by just linear motion minimizing the energy losses in motion transfer. The nozzle used is according to the international standards. Also, we researched that at 47° of nozzle we get the maximum flow rate of granules. The piston cylinder arrangement is kept pneumatic instead of than hydraulic to avoid oil leakages and slipperiness. Refer Figure-8.

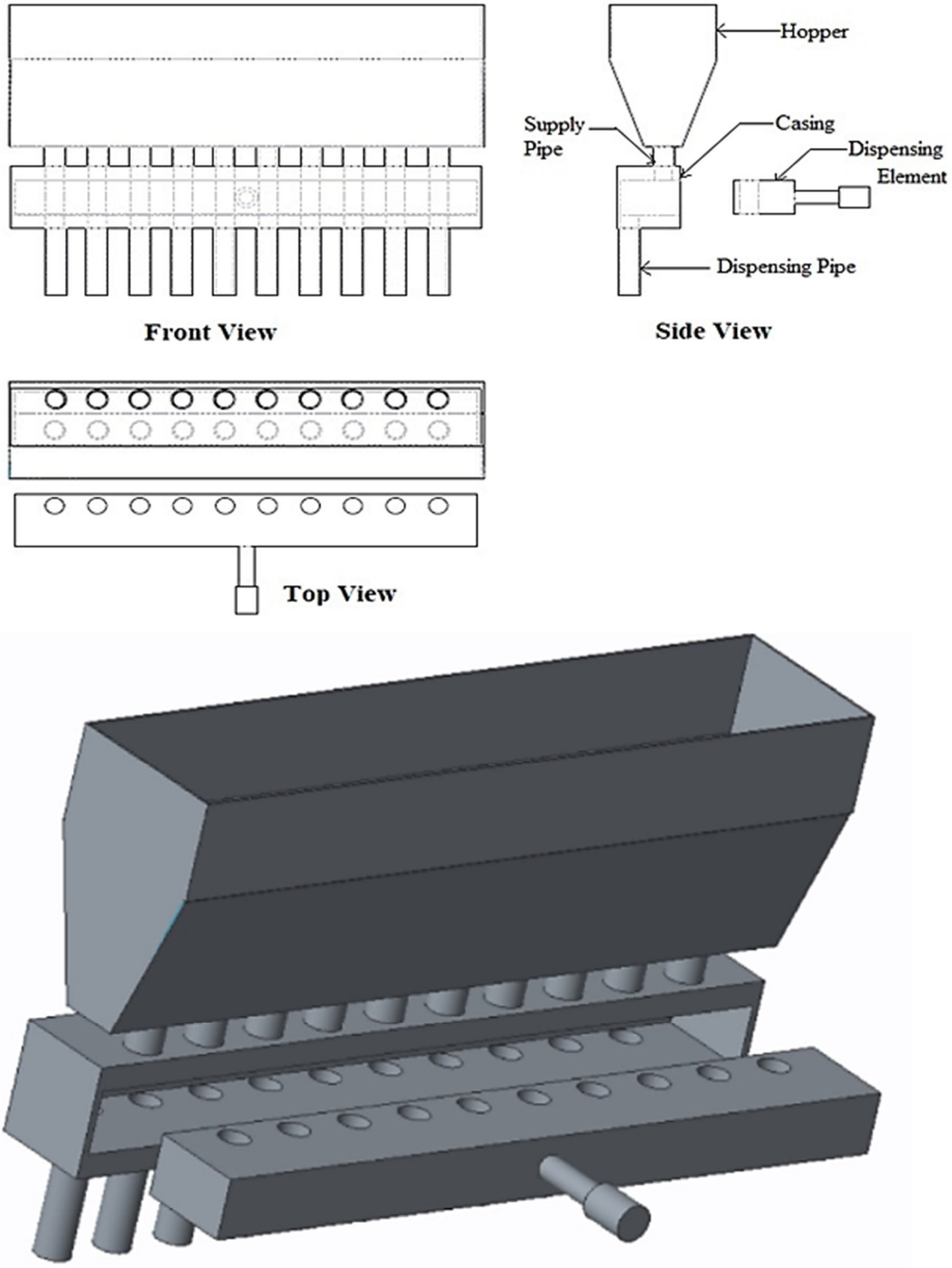

Figure-8: New Design (2D & 3D View)

After improving the design, we got following results and graphs:

Table-3: Weight in can (After design improvement)

Subgroup	Weight in can (Gram)									
	1	2	3	4	5	6	7	8	9	10
1	1	1.5	1.7	0.9	2	1.6	1.7	1.5	1	1.2
2	1.6	1.7	2	1.1	1	1.4	1.9	0.9	1.5	1.8
3	1.7	1.8	1.9	1.6	1.5	1.3	1	1.6	1.5	1.1
4	0.9	1.5	1.2	0.8	1.1	0.9	1.2	1.5	1.7	1.9
5	1.6	1.3	1.8	2	1.4	1.3	1	1.5	1.4	1.6

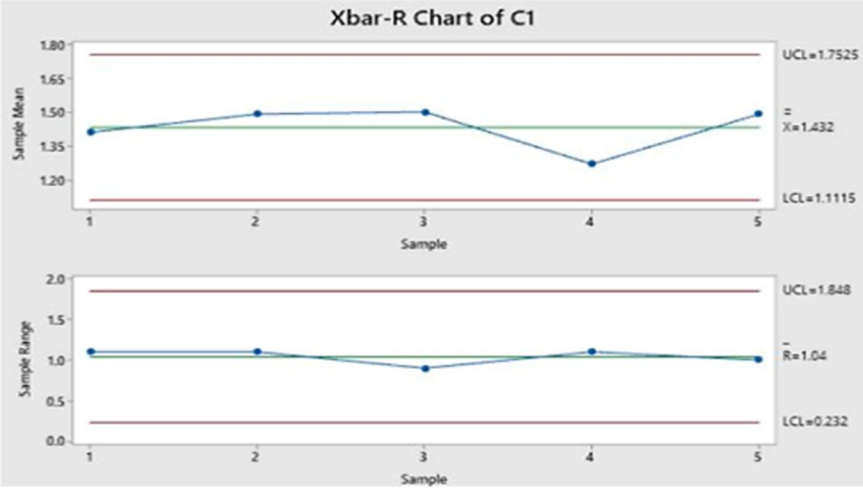

Figure-9: New X-bar & R Chart

Table-4: New Sigma and DPMO Levels

Sigma	Yield (%)	DPMO
1.3	43	570000
1.4	46	540000
1.5	50	500000

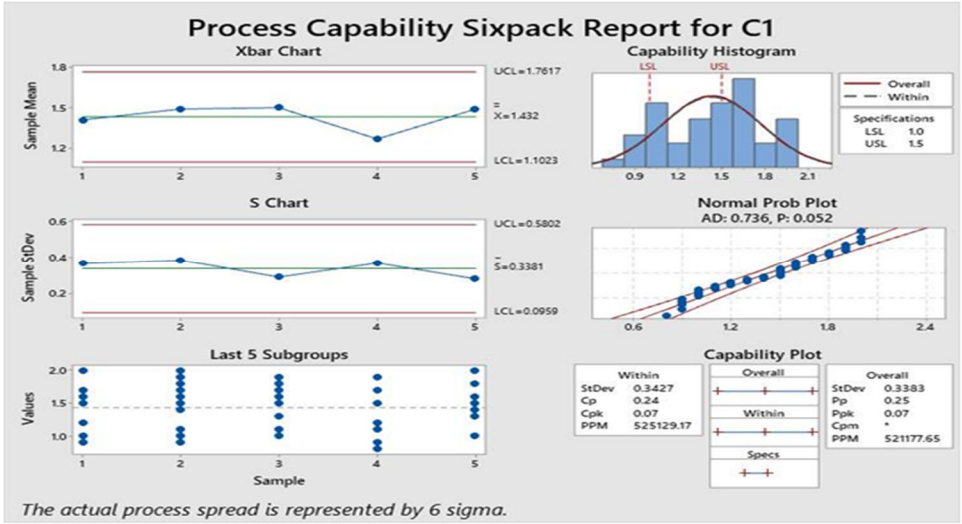

Figure-10: New Six-pack Analysis

Now as the design phase was completed by making a simple prototype, we tested our design and applied six sigma to the same and the results which we got were amazing. The design fulfilled our prescribed standard with just 7 to 12% tolerances and also the sigma level nearly tripled beyond our expectation of doubling. The new analysis shows the value of Process capability (Cp) 0.24 and Defect per million opportunity (DPMO) is 55512.17.

E. Control

Once improvement is achieved, it is not necessary that it will not stay as it is for life long. Process mean is always deviating with time due to many factors like, variation in raw material evenness, inadequate maintenance. So, to maintain the achieved improvement control over the process is must. In order to maintain the improvement achieved regular maintenance of moving parts and pneumatic system is required. It is also important to regulate evenness of raw material.

III. CONCLUSION

After applying Six Sigma Methodology and going through various steps of it our aim was to achieve a 50% increase in Sigma level but beyond our expectation it increased 150%. Apart from its application of Six Sigma Methodology resulted in better and power efficient design. Also, the tolerance level was also maintained in new design of 7 to 12%. Along with it the operation and maintenance of new design was smooth than the previous one.

A. Further Advancement

We worked on the principle of “Small investment Big returns” in which precision was not given much value. So, if the money is not concern then we can use PLC circuit and also different types of electronic gadgets to enhance our productivity; also, we can make our machine work hassle free. But our main focus is small and medium size entrepreneurs and industry because government is encouraging those industries. Also, the household food and dairy industries are flourishing at magnificent rate. So, the investment is less and expectations are more.

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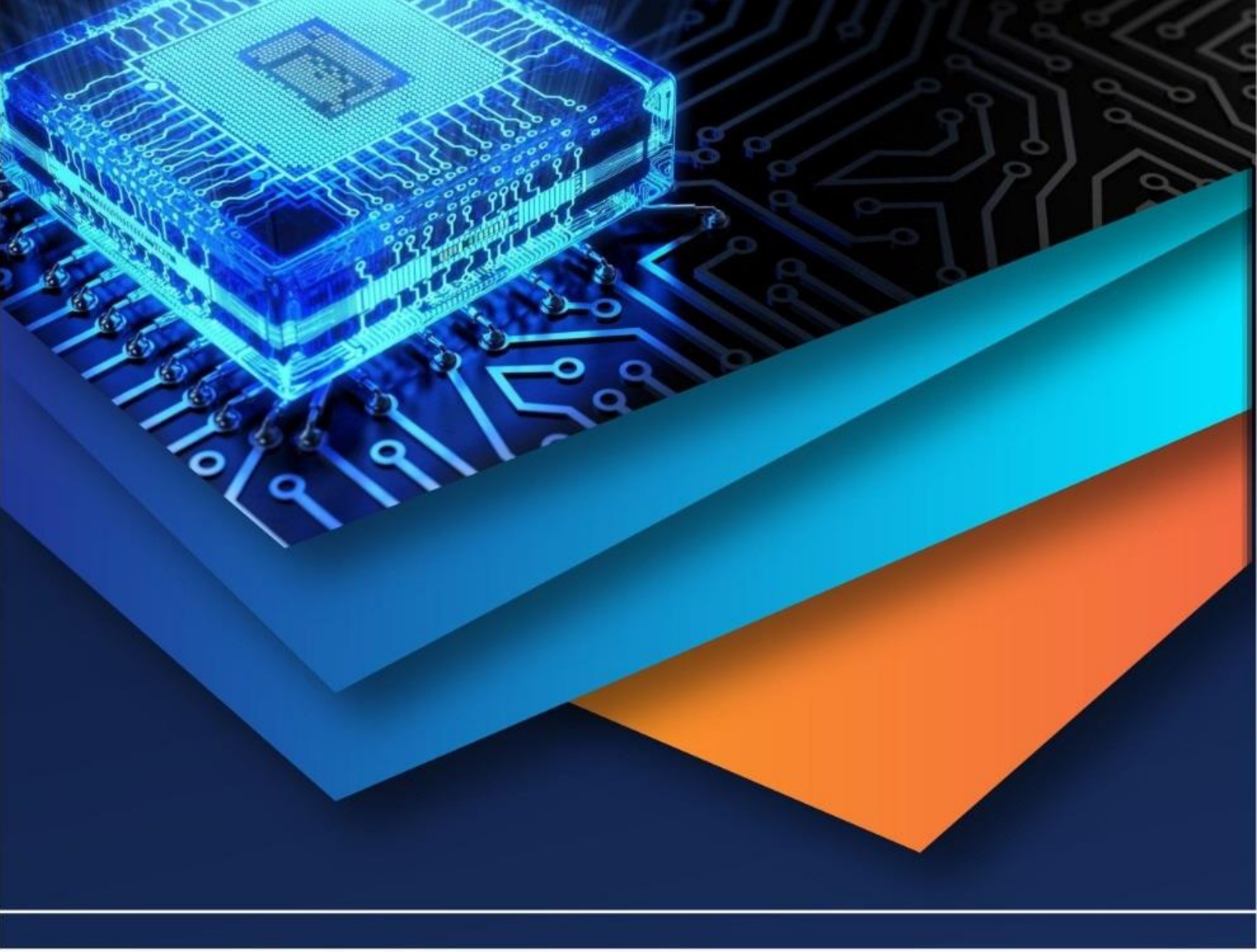

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