iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** VIII **Month of publication:** August 2016

DOI:

www.ijraset.com

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Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Reduction of scrap on honing machine through DMAIC approach

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Abstract—DMAIC is an enhancement strategy for attaining customer satisfaction by reducing variation and thus producing products and services better, faster and cheaper. This study of DMAIC approach is on project how the DMAIC methodology and statistical techniques were applied to resolve the issue of manufacturing process capability. This project has substantially benefitted the organization by reducing the scrap when piston rings are honed in honing machine, achieving zero rejection and improving the on time delivery. By using appropriate qualitative and quantitative tools in different phases of the DMAIC methodology, the critical output, key process inputs and root causes were identified, analyzed and validated. This project methodology can be used in general to reduce process variation for any other manufacturing processes as well, which will help in improving customer satisfaction.
Keywords—DMAIC (Define – Measure – Analyze – Improve – Control)

I. INTRODUCTION

Six-Sigma is a philosophy, a measure and a metrology that provides business with the perspective and tools to achieve new loads of performance both in service and product. In Six-Sigma, the focus is on process improvement to increase capability and reduce variation. The Six-Sigma methodology aims to reduce the number of mistakes/defects in a manufacturing process and hence the manufacturing costs.

In this changing scenario of globalization the consumer expectations are increasing and changing very fast and companies must be quick to adapt them if they want to survive and thrive. In a competitive environment which progressively tightens every company claims to own the excellence and competitiveness hence, probabilities to win the competition become greater. As firms improve their processes, and move towards the exclusive Six-Sigma, they often need to redesign the products, process and services to "design-out defects and design-in quality". In its broadest sense six sigma is a methodology that firms can use to improve the output quality of a process. Six-Sigma has its roots in the repetitive processes of manufacturing; however, the same tools can be used in any business process firm hiring new people to effective product design and marketing plans. The foundation of the Six-Sigma programs is statistics; Sigma stands for standard deviations from the mean of a data set in other words a measure of variation, while six sigma stands for six standard deviations from the mean. When a process reaches the six sigma level that process will be running close to perfection, producing a mere 3.4 defects per million. By using statistical and analytical tools firms can reduce the amount of variation in a process by removing the causes of variation therefore increasing the output quality of the process.

Six-Sigma is a part of proactive business strategy that is planned, executive, monitored, steered towards success, and nurtured by the executive management of the deployment organization and also provides companies with a series of interventions and statistical tools that can lead to breakthrough profitability and quantum gains in quality, whether the products of a company are durable goods or services. There has been a tremendous amount of discussion around defining Six-Sigma in terms people within your business or organization can understand.

II. LITERATURE REVIEW

A. Hongbo Wang, presented an equation to calculate the allowable manufacturing variation in bump height and thereby to ensure six sigma manufacturing success in the manufacture of six sigma quality, high density interconnections.

B. Song-Kyoo Kim, have applied six sigma tools to product line business plan development to reduce variation and improve the effectiveness with which they conduct their day to day business activities. Further, they have implemented the DMAIC model for achieving the goals of manufacturing company.

C. Wang Yachao, have introduced the status of Six-Sigma implementation in service in the past and present, and then overviewed some studies of implementing Six Sigma in service, especially in banking sector. Further, they have applied DMAIC model in one short process and used control chart to identify special variations in a process.

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Volume 4 Issue VIII, August 2016
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III. CASE STUDY

A. *Define phase*

The first phase Define refers to describing something accurately. Purpose of Define phase is to state the problem precisely which ensures that the project has a greater chance of success. Steps of this phase related to the project are as follows:

1) *Problem statement:* High honing scraps in chrome finish section causing the wastage of resources as well as in production target to lead to the low customer satisfaction level
2) *Goal Statement:* Scrap reduction of honing machine.
3) *Project scope:* Through this project we learn how six sigma techniques are used to improve the productivity by using quality tools. We learn how to calculate scrape during honing process of the rings and also learn how to calculate the percentage of scrap at every process.
4) *Project constraints:* Different types of rings are analyzed covering the K1, GOE-13, KV1, 1KA etc. from the grinding section to the final inspection. Improvement will be tried on the effective result of the trial lot covering all the sizes.

Name of the phase

Define Phase- - - - - - - - - - Plan
Measure Phase - - - - - - - - Do
Analyze Phase - - - - - - - - Do
Improve Phase- - - - - - - - Check
Control Phase- - - - - - - - - Act

5) *Loss at glance:* It is observed that there is quite high loss on honing machine which was contributing 23%in the 1st quarter, 23.6 in the second quarter and 23.4% in the last quarter in the last year. Recently the scrap is about 23.2%.This project was required high intension to work on as to meet the target of the production.
6) *Impact of loss:* It impact adverse effect on the production and the company. It demotivates the worker as he is not able to achieve its target and consequently reduces his productivity. While working on the project we came to know that the average scrap on honing machine was about 23 %, so it impact bad both on resources and time ultimately leads to loss. We came to know that 23% loss means it comprises 32, 00,000 INR per annual.

B. *Measure phase*

The second step on the six sigma roadmap is to measure performance of the process. By doing this phase we determined the vital few factors that influenced the behavior of our process. Measurement is the key transitional step that enabled our team to refine the problem and begin searching for the root causes. It analyses current performance levels and identify goals you hope to achieve integrate visual presentation flow chart, cause and effect diagrams, process control charts etc

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Volume 4 Issue VIII, August 2016
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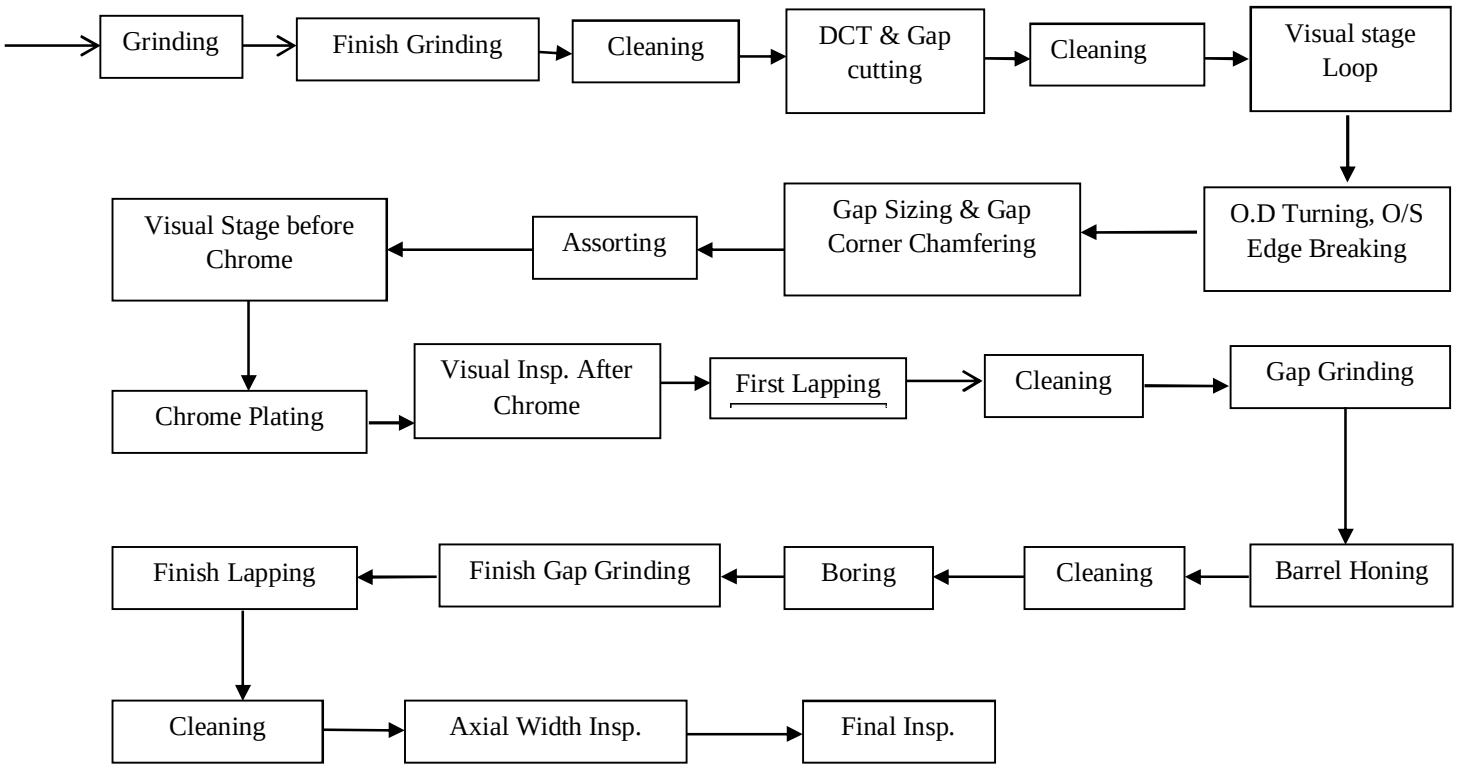
Process Flow Diagram

INPUT (RING BLANKS)



Past data of machining rejection

This is the record of the data collected from the final inspection

INPUT	84225			
GOOD	61104	Type	Gk110cb	
MACHINING SCRAP	19356	Size	85.0-120.0	
MACHINING SCRAP %	22.98%			
DEFECT	QTY	%age	Cumm.%	Cumm. Qty
HONING	4565	5.4%	23%	4565
VISUAL DEFECT BEFORE CHORME	1740	2.1%	32%	6305
CHR DEFECT FINAL	1717	2.0%	41%	8022
CHR PLATING	1569	1.9%	49%	9591
OTHERS	1300	1.5%	55%	10891
NON UNIFORM	1116	1.3%	61%	12007
VISUAL DEFECT AFTER CHROME	1000	1.2%	66%	13007
UNTURNED MIX	938	1.1%	71%	13945
FIRST LAPPING	901	1.1%	76%	14846
FINISH LAPPING	895	1.1%	80%	15741
AXIAL	824	1.0%	84%	16565

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GAP SIZING	685	0.8%	88%	17250
ROUGH GRINDING	680	0.8%	91%	17930
DCT/GC	606	0.7%	94%	18536
FINISH GAP GRINDING	420	0.5%	96%	18956
DFS	400	0.5%	98%	19356

Table 1. Data for Pareto before improvement

In this table data of scrap has been collected of chrome compression rings. This table illustrates the rate of scrap at different level of operations and their contribution to the scrap as the input is around 84225 and the output is around 61104. The amount of scrap is about 19356 which lead to 22.98% of total scrap.

Pareto of chrome compression piston ring

As we can see that bar of honing almost contributes 23% of the total scrap rate. There are other contributors also but they are less contributing than honing.

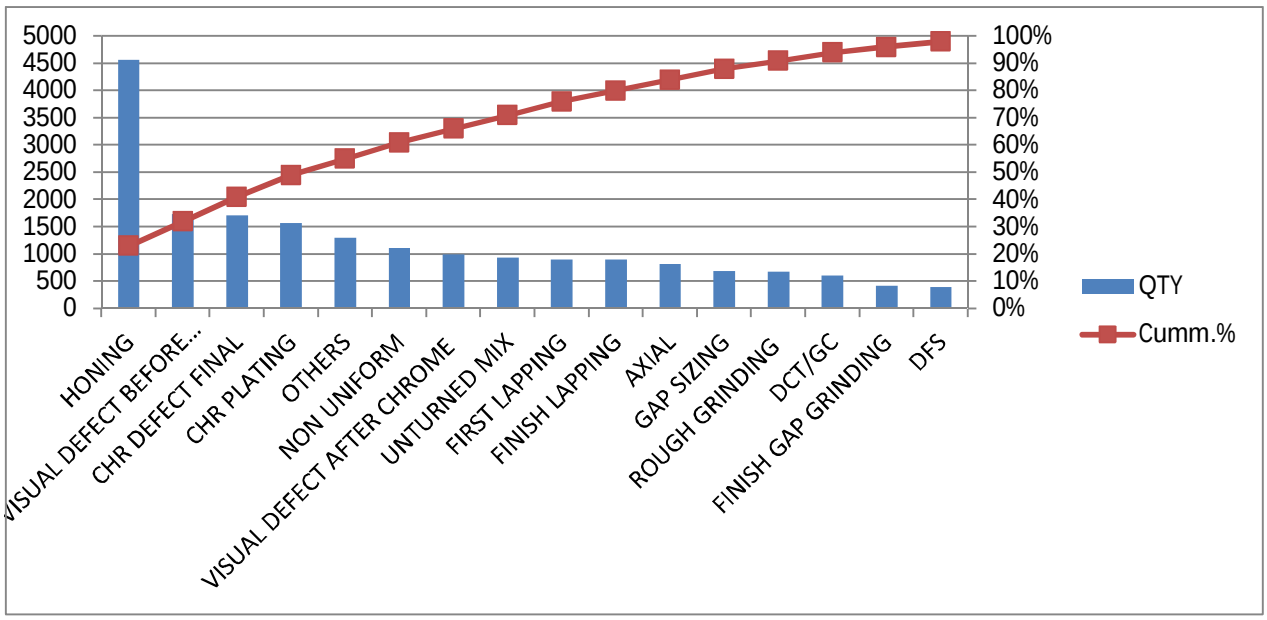

Figure 1. Pareto chart before improvement

C. Analyze phase

Measure phase has provided adequate data to the team for analysis. The analyses and the data show that we are using high tolerance limits during assembly of shaft. The focus in the analyze stage is on stabilizing the process. It involved monitoring the process using different techniques such Brainstorming, Cause and Effect Diagram, Pareto Analysis, Capability Analysis and identifying the specific causes of variation.

1) *Brain storming and cause & effect diagram:* Brain storming session was conducted to identify the probable causes of failure. The following points have been emerged during the session. The points were arranged as the logical causal chain in Cause and Effect diagram.
2) *Major defects with root cause analysis:* This is the description of the whole defect of the Edge breakage of the chrome piston ring.

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Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
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More and more rings with gap breakage were being produced after honing process. This was because of no pre gap operation was being carried out before the honing process. As gap is the measure defect we have to control it.

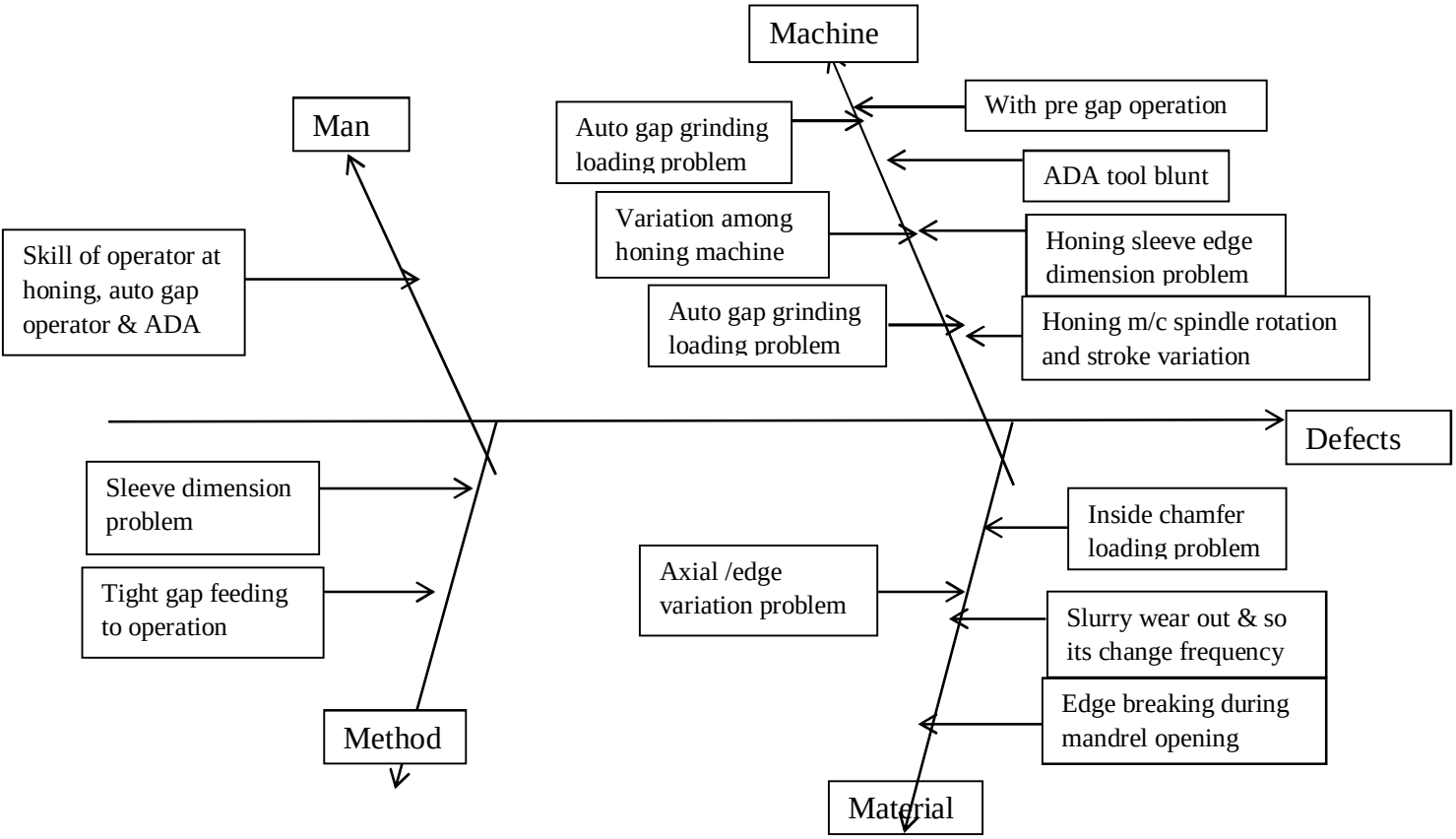

Figure 2. cause and effect diagram

Problems were found during honing process as:

Excessive honing at gap ends due to stress relieving.
Uneven honing at gap ends due to less pre gap.
Excessive honing time.

Factors that contributing to the honing machine

Tooling.
Slurry condition.
Rod.
Sleeve size.
Time required for honing process.
Emery solution which is mix with the coolant.

Factors contributing to the honing process

A.D.A. light checkup and radial thickness.
Sleeve used is not of appropriate size according to the ring size and type.
Using up the sleeve beyond the maximum permissible size limit.
Belt grinding of rings.

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Volume 4 Issue VIII, August 2016
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D. Improve Phase

Cause validation and improvement

Sr. No.	Potential Cause	Criteria	Observations	Ok Not ok	Cause Yes No
1	Skill of operator	Skill matrix	Operators defined skill level	Ok	No
2	Loading of ring not proper at honing sleeve	Skill matrix	Spindle alignment against the sleeve	Ok	No
3	Outside edge chamfer problem	As per process sheet	Sampling done in one of the size (95.0std)	Ok	No
4	Tool blunt at ADA	Periodic checking at the start of setting & the quality of ring		Ok	
5	Honing sleeve edge dimension problem	Edge dimension fixed	Sampling done visually	Ok	No
6	Without pre gap operation for honing	As per process sheet	Gap breakage at honing due to without pre gap operation data.	Not Ok	Yes
7	Slurry wear out, so its change frequency	As per control plan	Changed twice in a month	Not ok	Yes
8	Variation among honing machine	As per process sheet	Some are in better condition	Not Ok	Yes
9	Tight gap input feeding to auto gap grinding	As per process sheet	Data collected at auto gap cutting m/c	Ok	No
10	Honing machine spindle rotation and stroke variation	As per control plan	Stroke – 20 m/min 30 rpm spindle rotation	Ok	No

Table 2. Cause validation for defects

Above mentioned defects are caused due to following reasons

1) A.D.A. light checkup and radial thickness.
2) Sleeve should be used of appropriate size according to the ring type and size.
3) Using up the sleeve beyond the permissible size.

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Volume 4 Issue VIII, August 2016
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4) Belt grinding of the rings.
5) Machines are not regularly maintained.
6) Time is not fixed for the honing process.
7) Pre gap is not appropriately provided in the rings.
8) Emery solution is not added in the proper quantity in the coolant and slurry is not changed at regular interval of time.
9) Sometime less skilled worker is worked on the honing machine while wen there is a shortage of worker.

Solutions obtained after brainstorming

a) *At A.D.A. machine:* Rings coming out from the A.D.A. machine should be correctly analyzed. Light checkup is done on the light checkup machine using the ring and contour, contour ring is just act like a sleeve, radial thickness can be checked out by using the radial thickness measuring instrument.
b) *Sleeve used is not of appropriate size according to the ring size and type:* Earlier the worker uses up the sleeve which was not of appropriate size according to the ring size and type. Initially workers were given a data in which sleeve size is defined for specific ring makes and types.
c) *Using up the sleeves beyond the maximum permissible size:* The workers were using up the sleeves beyond the maximum permissible size. This was the major factor contributing to the scrap of the rings. As after a certain increase in the sleeve size of the rings that are produced in the sleeve have a disturb geometry which can't be tolerated. This can only be done if the input is correct.
d) *BELT grinding:* Machine should be properly maintained with new rollers used and various angles of the rollers were corrected according to the manual.

Setting up of the rundomat machine.
Right side:
Front rollers: 5 degree on left
Bottom rollers: 5 degree on right back rollers: 5 degree on left
Left side:
Front rollers: 5 degree on left
Bottom rollers: 5 degree on right back rollers: 5 degree on left

A trial lot of rings after belt grinding were followed and honing was carried on. It was observed that rundomat helps in increasing up the productivity, as the time required by the honing process get reduced

e) *Time:* While operating the honing machine workers sometime give more time and sometime less, which can cause the ring less honed or more honed. If the rings are less honed then it must be reworked and if more honed the ring will be of poor quality. Time should be set for each standard type and size of the rings. It should be mentioned in the process sheets.
f) *Pre gap:* During honing process the sometime breakage is notified. To avoid the breakage of the ring pre gap must be provide.
g) *Machine:* Machine should be regularly maintained.
h) *Slurry (coolant and emery solution):* Earlier coolant is not appropriately mix with emery solution. While during operation slurry used without appropriate emery solution doesn't give desire result, as it losses it property cause wearing of the surface which consequently leads to more honed ring, so appropriate amount of emery solution is mixed with the coolant. On regular interval which is about every two weeks.

Only skilled workers should be worked on the honing machine.

Present data of machining rejection

INPUT	88560
GOOD	78330
MACHINING SCRAP	17388
MACHINING SCRAP %	19.63%

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Volume 4 Issue VIII, August 2016
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DEFECT	QTY	cumulative	Cumulative Percentage
HONING	2566	2566	14.76
VISUAL DEFECT BEFORE CHORME	1540	4106	23.61
CHR DEFECT FINAL	1633	5739	33.01
CHR PLATING	1509	7248	41.68
OTHERS	1350	8598	49.45
NON UNIFORM	1210	9808	56.41
VISUAL DEFECT AFTER CHROME	1080	10888	62.62
UNTURNED MIX	950	11838	68.08
FIRST LAPPING	985	12823	73.75
FINISH LAPPING	844	13667	78.60
AXIAL	750	14417	82.91
GAP SIZING	517	14934	85.89
ROUGH GRINDING	650	15584	89.63
DCT/GC	778	16362	94.10
FINISH GAP GRINDING	521	16883	97.10
DFS	505	17388	100.00
	17388		
		14.75730389	

Table 3. data for Pareto after improvement

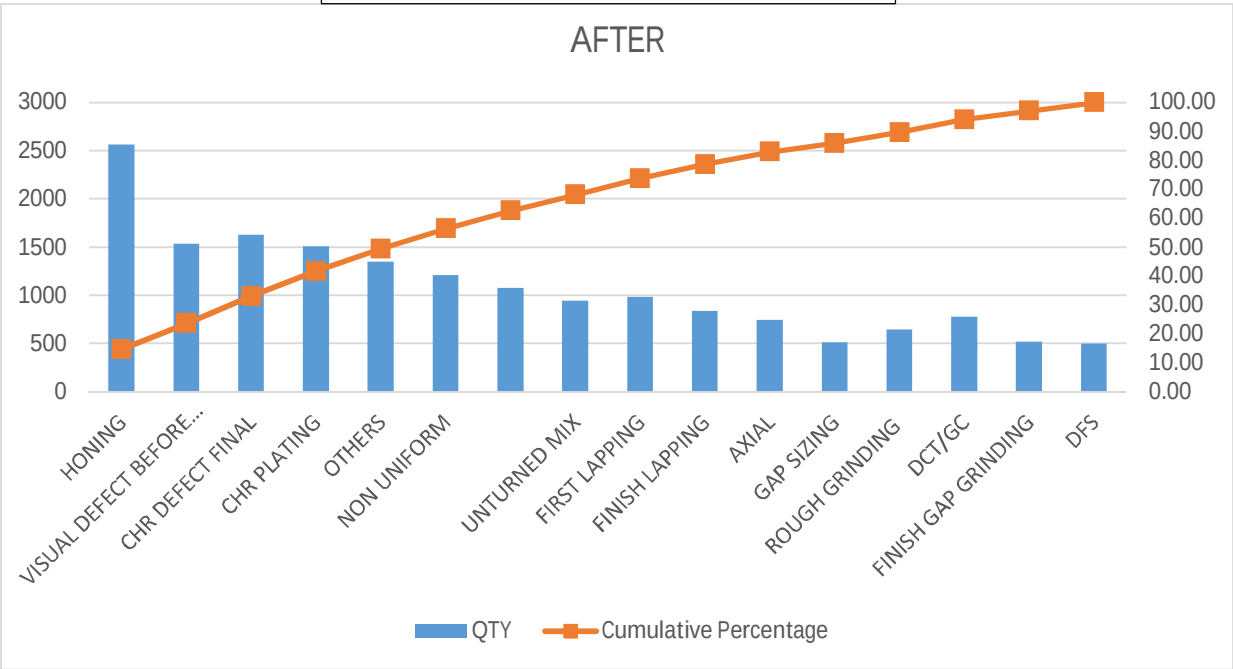

Figure 3. Pareto chart after improvement

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E. Control Phase

As we had mentioned about how we find the step by step solution in order to reduce the scrap generation. The result obtain by this process, we have to control it in order maintain the productivity. Various step for controlling the results as:

1) By providing control charts and shift sheets on each machine and training given to the operator how to fill it.
2) By regularly checking the operator whether he is filling the charts after checking the rings or not
3) Visually check around 10 rings in every lot for "LIGHT PASS" test.
4) To check whether any kind of light pass on periphery of the ring.
5) Check all the parameter of the ring with the help of instruments that are provided to operator.
6) Calibrated the instrument at regular intervals.
7) Testing is held intermediately.
8) Scrap rings were being scratched and throw in the scrap bin.

Responsibilities

Time bound responsibilities were assigned to the members of the team.

1) Training was given to operator.
2) Team members were divided and responsibilities are divided as;
a) Some had to be checked whether the control chart and shift charts are filled regularly after checking the each packet.
b) Some executive had given the responsibility to visually check the rings for any visual defects that could have occurred due to machine or other negligence
c) All parameter were to be personally checked by the members on the round.
d) Some executive had given the duty to regularly calibrated the instrument and prepare a document for it.

All reports, chart and documents prepared were given to the concerned supervisor.in order to control the scrap generation and improve the productivity.

IV. CONCLUSION

The aim of the project to reduce the scrap generated during honing process optimizing of the available resources. Scrap generation during this process is quite high which contribute 23% of the overall scrap generation. Scrap generation is an obstacle in achieving the targeted productivity. Analysis of collected data using different tools brought out some clear-cut solutions. This project unfastened the path for a new culture and shared aims in our organization. Response of employees was remarkable.

Involvement of leadership in imparting proper training and motivation to employees can lead to the identification of many such projects. A thorough understanding of needs of employees and proper addressing of suggestions/points is the need of the hour.

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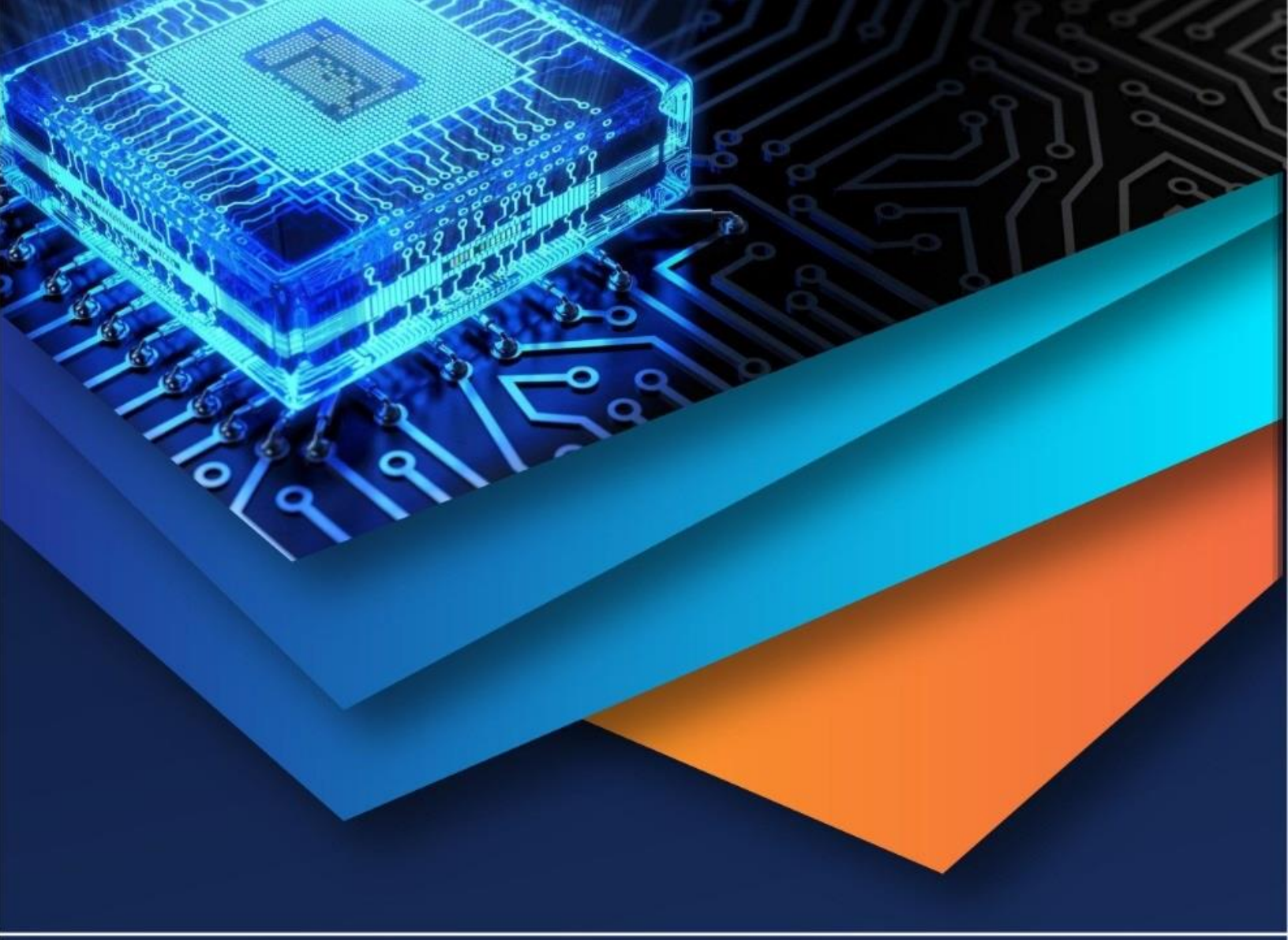

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