Design and Analysis of Chute System to obtain World Class OEE

Mayur N. Nagdiya[1] Mr. Kiran Bhabhor[2]
[1]M.E. Student [2]Associate Professor
[1,2,3]Department of Mechanical Engineering
[1,2]GEC Dahod, GTU, Ahmadabad

Abstract— A large investment in a piece of capital machinery and, in theory, it could run 24 hour a day for seven days a week at its optimum Speed. If it did this you gain the maximum value from the investment. In reality there is number of element that can affect the value gained from the investment. So that fully utilization of equipment can be done. Hence for fully utilization of any equipment any firm must have to calculate OEE. This paper represents the methodology applied in increasing the OEE of an Organization by exchanging the feed mechanism from a conveyor to a Chute system.

Key words: OEE, Conveyor, Availability ratio, Performance ratio, Quality ratio, Chute Design, Analysis of Chute system, world class OEE

I. INTRODUCTION

In every developed country, it is the manufacturing industry that has spurred economic growth. It not only creates wealth but more importantly, absorbs and recreates the same many times over, within the economy. This is also true for India where the growth in manufacturing sector will provide the necessary impetus to a sustained growth of the economy forward and create employment opportunities for our people.

Nowadays many companies are interested to improve their maintenance system. Because, they have come to know that this is the system through which companies can reduce the cost of their products and can develop a reliable production process. A well designed maintenance structure can be helpful for the companies to get the competitive advantages. But majority of companies are not able to manage a maintenance system. The two main reasons for that are the lack of proper measurement and the lack of control systems for maintenance. The main goal of the maintenance is to reduce the failures of the industrial plant, machinery and equipment's. This goal can be achieved by using different maintenance approaches such as corrective maintenance and preventive maintenance etc. A good maintenance approach and schedule can not be 100 percent effective at all the time. Unforeseen equipment breakdowns and requests reduce the efficiency of the plan. Even now a good maintenance schedule can get 70 to 90 percent efficiency. The idea with this project is to see the current situation of the company. Is the company using its manufacturing equipment's in a proper way to get the competitive advantages? If not, then find out the main reason for that.

The word, convey means to move. In the manufacturing industry, conveyor belts are designed to move products from one point to another or through a chain of assembly. Conveyor belts are designed for light and heavy duty applications.

- Conveying product: Conveying belts can transport products either in a straight direction or through directional changes and elevation. The purpose of the belt is to provide controlled movement of product. Belts are designed in different sizes; systems used to run the belts operate in different speed ranges.
- Manufacturing Uses: Conveyor belts are also used to transport material into processing equipment and back out again. These belts optimize productivity. In the food industry conveyors are used deliver the product to cooking or sealing equipment, then off to packaging.

Conveyors are durable and reliable components used in automated distribution and warehousing. In combination with computer controlled pallet handling equipment this allows for more efficient retail, wholesale, and manufacturing distribution. It is considered a labor saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volume with smaller storage space and with less labor expense. There are two main industrial classes of belt conveyors; those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport industrial and agricultural materials, such as those used to transport industrial and agricultural materials such as grain, coal, ores, etc. generally in outdoor locations. Generally companies providing general material handling type belt conveyors do not provide the conveyors for bulk material handling. In addition there are a number of commercial applications of belt conveyor.

OEE is the series of matrices which can be used for the utilization of machine at the job level, shift level, overall plan or enterprise level. OEE is stands for overall equipment effectiveness. Essential it is a single figure that significances the utilization of machine. This can be at a job level, shift level, overall plan or enterprise level. OEE is a measure of total equipment performance. OEE is also a three part analysis tool for equipment performance based on actual availability, performance efficiency, and quality of product or output. OEE percentage is a calculated relative comparison metric used for a specific equipment or process over a period of time.

OEE is broken down into three measuring matrix of:

- Availability ratio (AR)
- Performance ratio (PR)
- Quality rate (QR)

A. Availability Rate (AR)

The availability rate is the time the equipment is really running versus the time it could have been running. A reduced availability rate is an indication of equipment failure and issues around setup and adjustment

Availability Rate = Run Time / Total Time

B. Performance Rate (PR)

The performance rate is the quantity of material produced during the running time versus the quantity of material that could have been produced when taking in to account the manufacturers documented speed of the equipment. A low performance rate can be seen as a result of idling minor stoppages and reduced speed operation

Performance Rate = Actual Prod. / Standard Prod.

C. Quality Rate (QR)

The quality rate is the amount of acceptable material versus the total amount of material that is manufactured. A low quality rate is an indication of startup losses and the amount of scrap material.

Quality rate = Good Count / Total Count

II. WORLD CLASS OEE

OEE is essentially the ratio of Fully Productive Time to Planned Production Time (refer to the OEE Factors section for a graphic representation). In practice, however, as we discussed above OEE is calculated as the product of its three contributing factors:

OEE = Availability x Performance x Quality

This type of calculation makes OEE a severe test. For example, if all three contributing factors are 90.0%, the OEE would be 72.9%. In practice, the generally accepted World- Class goals for each factor are quite different from each other, as is shown in the table below.

III. OEE FACTOR WORLD CLASS

A. AVAILABILITY 85%

B. PERFORMANCE 100%

C. QUALITY RATE 100%

So as above,

OEE 85%

Of course, every manufacturing plant is different. Worldwide studies indicate that the average OEE rate in manufacturing plants is 60%. As you can see from the above table, a World Class OEE is considered to be 85% or better. Hence comparing organization's OEE and world class OEE we seen that the company OEE is very low compare to world class OEE, so our target is to achieve that figure.

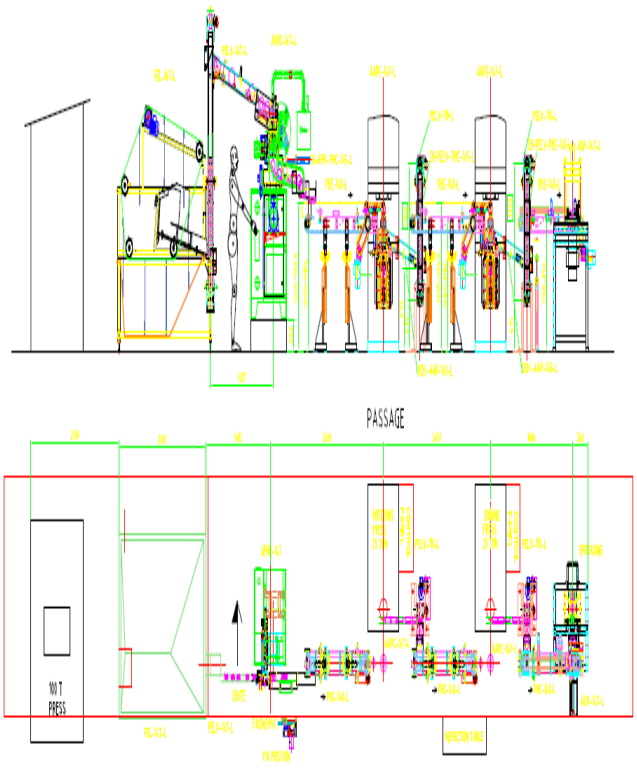

Fig. 1: Older arrangement

Here we can get idea about the exect arrangement of the conveyor system from the above figure. Here company will not provide the actual picture of the system as per the company norms so we just have to take above arrangement and we can get the result of the system by the experimental data as per the follows.

IV. CALCULATATION OF OEE WITH CONVEYOR

In HARSHA ENGINEERS LTD. On 15th of March the data for OEE during one shift are as below,

SPM of press is 250

L+UL time 3

Batch no SLAC1303126

Item R - 30 - 76XJ NSK (SUZHOU, CHINA)

Shift A

No of pockets 18

Line 4A

A. Now for the calculation of Availability,

Total availability = 510min

Available Min = 405 min

Total Down Time = 105 min

So, by definition of availability,

Availability Rate = Run Time / Total Time

Here run time is 405 and total time is 510

Availability % = 405/510

Availability % = 79.41%

B. Now for calculation of performance rate, Piece per minute = 8.19

Standard production rate = Act. Planned min. x piece per min. = 3480.00

Performance efficiency % =

= actual Production / standard production

=3283 / 3480

Performance efficiency % = 94.33 %

C. Now for calculation of quality rate,

No. Scrap part = 179 pices.

By definition of quality rate,

Quality rate % = Good Count / Total Count.

= 3104 / 3283

Quality rate % = 94.55%

Now by the definition of the OEE, OEE is calculate as,

OEE=AVAILABILITYx PERFORMANCE x QUALITY RATE

= 79.41 % x 94.33 % x 94.55 %

OEE = 70.82 %

As above system we can get OEE increases but the drawback is, AR and QR decreases. So it's not effective in process to continuous work and also effective OEE.

This way we started the analysis again. Our target OEE is 85% whereas OEE achieved is 70.82 % so further modifications are to be done by analysis and data collection.

Hence our main focus is on first pillar i.e. overall equipment efficiency. Today Harsha's bench mark is 70% OEE. But as per world class OEE measure is 85% for a single line. So we have to achieve that target for achieving company's goal.

So after achieving 85% OEE we have increase the production. Also improve in quality of product and performance of machine.

After the study in company about the sources of alternative system which can easily replace the existing system we can conclude that mounting of in house CHUTE can perform better than the belt conveyor system. So we can use it and achieve our goal to mounting chute and remove conveyor to improve OEE.

Chutes used in bulk handling operations are called upon to perform a variety of operations. For instance, accelerating chutes are employed to feed bulk materials from slow moving belt or apron feeders onto conveyor belts. In other cases, transfer chutes are employed to direct the flow of bulk material from one conveyor belt to another, often via a three dimensional path. The importance of correct chute design to ensure efficient transfer of bulk solids without spillage and blockages and with minimum chute and belt wear cannot be too strongly emphasized. The importance is accentuated with the trend towards higher conveying speeds.

Chute flow patterns are described and the application of chute flow dynamics to the determination of the most appropriate chute profiles to achieve optimum flow is illustrated. The influence of the flow properties and chute flow dynamics in selecting the required geometry to minimize chute and cage wear.

Undoubtedly the most common application of chutes occurs in the feeding and transfer of bulk solids in production department.

Chute should be symmetrical in cross-section and located central to the system. In-line component of the solids velocity at the exit end of the chute should be matched, as far as possible. This is necessary in order to minimize the power required to accelerate the solids to the belt velocity, but more importantly to minimize abrasive wear of the belt. Normal component of the solids velocity at the exit end of the chute should be as low as possible in order to minimize impact damage of the belt as well as minimize spillage due to particle re-bounding.

Slope of the chute must be sufficient to guarantee flow at the specified rate under all conditions and to prevent flow blockages due to material holding-up on the chute bottom or side walls. It is implicit in this objective that the chute must have a sufficient slope at exit to ensure flow which means that there is a normal velocity component which must be tolerated.

D. Modeling in Pro-e

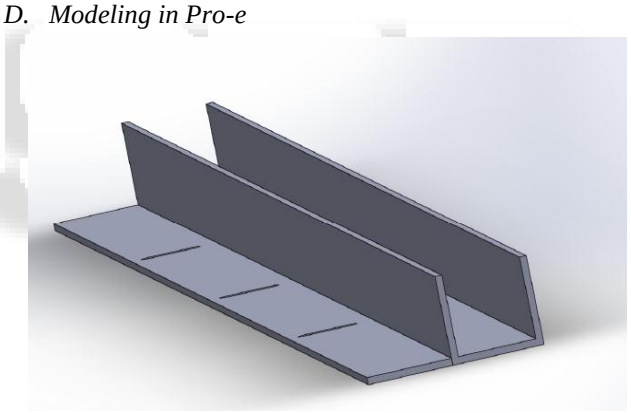

Fig. 2: Assembly of Chute

We can see the exact shape of chute which can be made in company inhouse. The material used for making of chute is structural steel and further step is analysis of cage which is carried out in this paper.

V. ANALYSIS OF CAGE

When cages are falling to chute, the effect of this is analyzed by Ansys software. Here we take cage of minimum size and we can see the effect on cages. Cages can easily passing through the chute but for experiment purpose we have to do analysis.

A. Geometry:

The Geometry of the cage is given in the following figure made in Ansys. In the following figure there is no load condition and the cage is in steady stage.

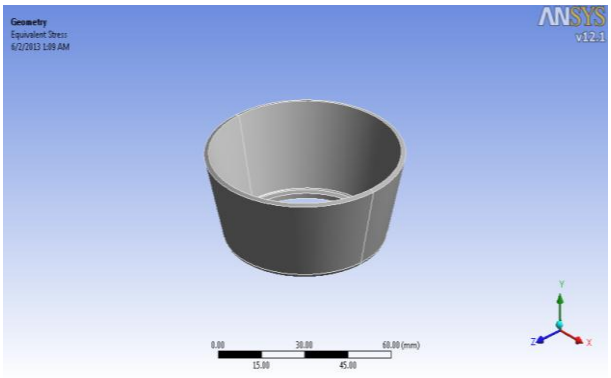

Fig. 3: Geometry of cage

B. Meshing:

The art of using FEM lies in choosing the correct mesh density required to solve a problem. If the mesh is too coarse, then the element will not allow a correct solution to be obtained. Alternatively, if the mesh is too fine, the cost of analysis in computing time can be out of proportion to the results obtained.

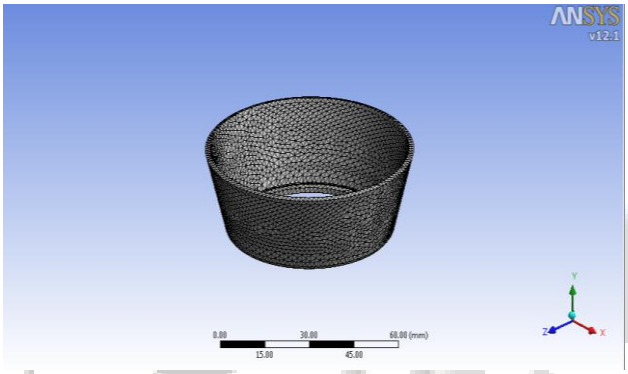

Fig. 4: Mesh Generation

C. Load Applied:

For the stress analysis point load is to be considered. Here cage is falling from 140 mm and for the safe implementation and experimental validation. Here for load calculation we have to use following equation.

F = m g h

Where,

F = Force means load applied.

m = Mass of cage 0.7 N

g = Gravitational acceleration = 9.81 m/s^2

h = Height from where cages are falling

=140 mm = 0.14 m

So, put value of all the parameter in the equation, we get,

F = 0.7 × 9.81 × 0.14= 0.96 N

∴ **F = 0.96 N**

For the stress analysis 0.96 N load applied on any point of the cage and we can get stress generation condition as stated below.

At point A 0.96 N load is applied where the point B remains Constant.

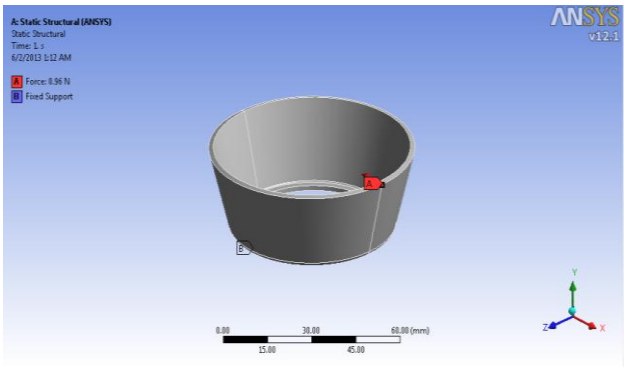

Fig. 5: Load applied on cage

D. Total Deformation

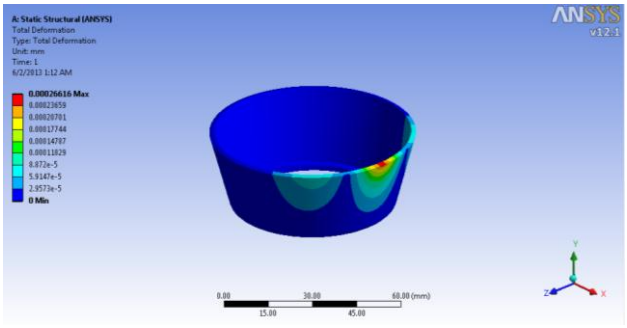

Fig. 6: Total deformation of cage

As per the above figure the slight deformation of the cage is detected remaining portion of the cage is safe at all. The point where the load is applied on point A, a small deformed face is seen.

E. Von Mises Stress:

Von Mises yield criterion is the first stress invariant. It is applicable for the analysis of plastic deformation for ductile material such as metals and get idea about the cage.

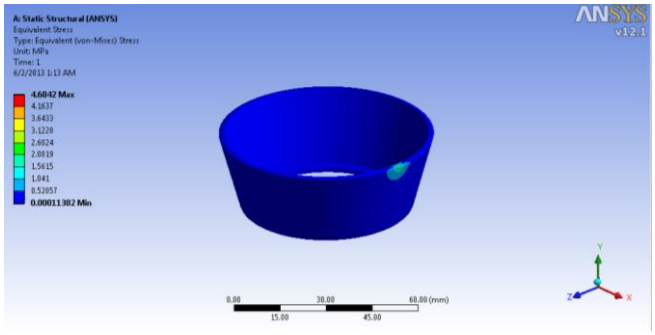

Fig. 7: Von Mises Stress

As per the above figure we can say that equivalent stress generated is in safe value. The point at which the load is applied is also in safe portion so we can easily say that this analysis is safe for the cage and also chute.

The value is near to 0.5 MPa and this value is safe as per the property of the cage material.

F. Maximum Shear Stress

Stress analysis is primary tasks for mechanical engineering involved in the design of structures and properties of materials and for the implementation of new system.

Here the cage is our structure and the maximum stress generated in the cage is in safe. The point at which the load is applied is also near to safe value.

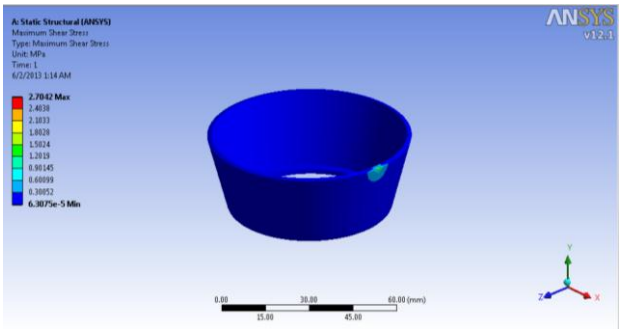

Fig. 8: Maximum Shear Stress

G. Von Mises Elastic Strain:

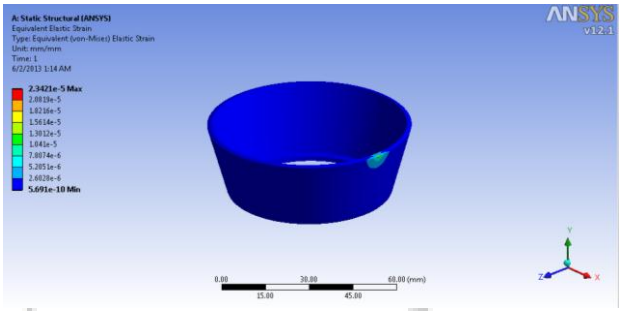

Fig. 9: Von Mises Elastic Strain

As above figure induced von Mises elastic strain is 2.6028×10 to 2.0819×10 which is almost in safe condition except point at which load is acted.

H. Maximum Shear Elastic Strain

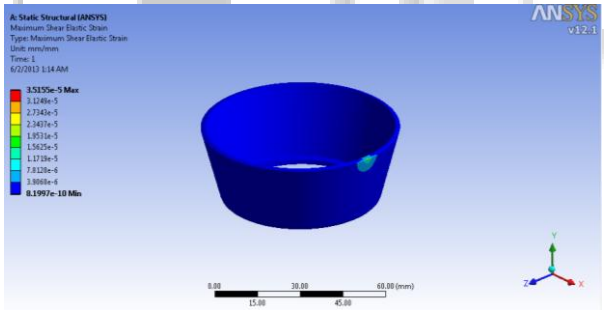

Fig. 10: Maximum Shear Elastic Strain

Here maximum induced shear elastic strain is nearly 3.1249×10^{-5} which is acted at the point of load. Remaining portion of the cage is in safe condition.

Now we conclude from above analysis that the cage will not deform except the point at which load is acted. So the use of chute is safe but in experimental validation we have to prove that cage is safe and no detect is to be generated in the cage.

Here Material of chute is structural steel so we can provide Nylon sheet on chute. Nylon sheet allow cages to go smoothly and it can minimize the defect in cages. We have to collect the data after the nylon sheet sticked on the chute surface from where the cage makes contact with it.

This material of sheet is shock absorbing so when cages falling from the height the deformation will not generated and by this QR increased and ultimately OEE also increased.

After the mounting the chute on our process following data are collected and the value of AR, PR, QR and OEE is calculated.

VI. CALCULATION OF OEE

By definition OEE is calculated as the product of availability, performance and quality rate,

OEE = AVAILABILITY x PERFORMANCE x QUALITY RATE

When we went to HARSHA ENGINEERS LTD. On 10th of April we collecting the data for OEE during one shift as below,

SPM of press is	250
L+UL time	3
Batch no	SLAC1304111
Item	R - 30 - 76XJ SKF
Shift	A
No of pockets	18
Line	4A

A. Now for the calculation of Availability, we calculate Availability,

Total availability = 510 min

Available Min = 430 min

Total Down Time = 80 min

So, by definition of availability,

Availability Rate = Run Time / Total Time

Here run time is 430 and total time is 510

Availability % = 430/510 = 84.31%

B. Now for calculation of performance rate, we calculate performance rate

Piece per minute = 8.19

Standard production rate = Actual Planned min. x Piece per min = 3520

Performance efficiency %

= Actual Production / standard production

= 3420 / 3520

Performance efficiency % = 97.15 %

C. Now for calculation of quality rate, we calculate quality rate,

No. Scrap part = 4 Pieces.

By definition of quality rate,

Quality rate % = Good Count / Total Count

= 3416 / 3420

Quality rate % = 99.88%

Now by the definition of the OEE, OEE is calculate as,

OEE=AVAILABILITY x PERFORMANCE x QUALITY RATE

= 84.31 % x 97.15 % x 99.88 %

OEE = 81.83 %

Here we get 81.83% OEE which is nearly 11% more than that of in Conveyor.

The following data are to be collected from the continuous observation and charts are generated to understand the variation on AR, PR, QR and OEE.

These data are collected through the whole production during the all shift and then the conclusion is to be taken.

VII. COMPARISON OF ALL DATA

From above all experimental and software analysis results are discussed below.

A. Comparison of OEE:

As per experimental data analysis the following graph is generated. In the following figure we can see the OEE of Chute system is about more than 80% as well as in the conveyor system the OEE is nearly about 70% and in Bowl Feeder arrangement it is nearly 65%. So it is clear that the OEE of chute is near to world class OEE which is our goal and it's an achievement for the company.

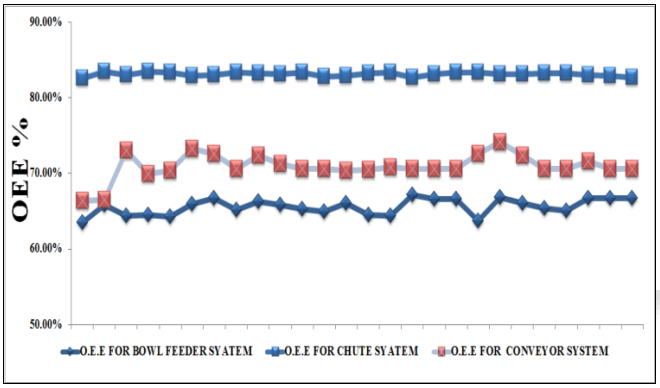

Fig. 11: Comparison of OEE

B. Comparison of AR:

AR of Bowl Feeder is nearly 80% and in the Conveyor it's about 75% but in the Chute system it is near to 85% and its value remains constant.

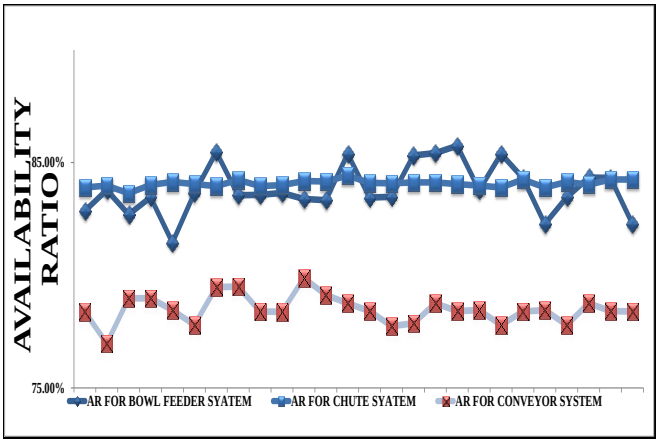

Fig. 12: Comparison of AR

C. Comparison of PR:

PR of the Bowl Feeder is nearly 78% and in the Conveyor it is 95%. Here by below graph we can easily see that the PR is about 99% and it is very much better than all the arrangement. The PR seems very high and it gives best performance which is desired from company.

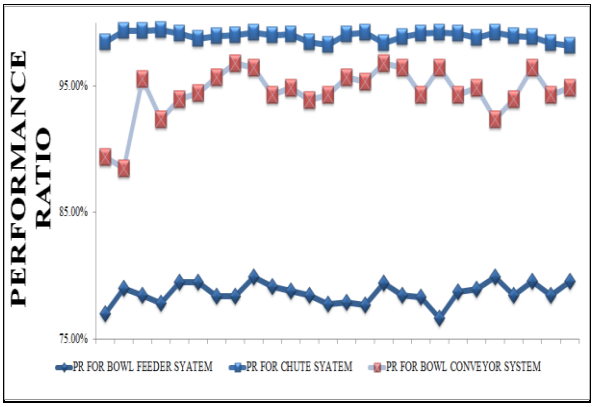

Fig. 13: Comparison of PR

D. Comparison of QR:

QR of the Bowl Feeder system is about 99% where as in the Conveyor system it is nearly 95%. In the Chute arrangement QR is more than 99% which is the higher value among all the existing system. Each and every company wants their production with zero percent defect but here we reached near these goal.

Quality directly affect the QR so Higher value of QR means higher quality and lower the value of defects and scrap and this is an achievement of our implement.

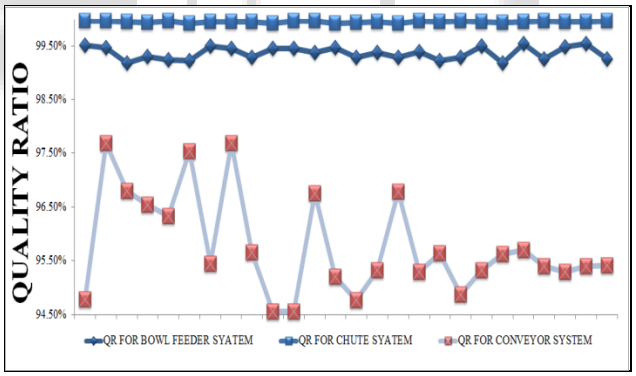

Fig. 14: Comparison of QR

E. Data Analysis

As per the above data of AR, PR, QR and OEE we can say about the following benefits:

- AR increased 4% that in the Bowl Feeder and remains nearly same in the Conveyor so it is affect the OEE and it increased as AR increased.
- PR increased 20% that of in Bowl Feeder and 5% that of in Conveyor so the PR also increased and ultimately OEE also increased.
- QR increased 5% that of in conveyor and nearly same that of in Bowl Feeder. This result shows that the Chute performs well when the QR matters for the company and these results increase in OEE.

VIII. CONCLUSION

Based on the experimental and software analysis we conclude that among all the system chute perform very effectively and we achieved our goal as per world class OEE. Here it is very clear that the AR, PR and QR are increased and by this OEE also increased which indicates our achievement over material flow interruption , various defects and scrap.

Same as study of actual data of AR, PR , QR of TRB cage line 4A we can see the experimental performance of Chute.

Finally we get the result which is very desirable for company and also very useful to future work for manufacturing of bearing cage.

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