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E: ISSN NO.: 2349-980X **Shrinkhla Ek Shodhparak Vaicharik Patrika**

Increasing Productivity by Line Balancing and Manpower Efficiency Improvement in Bearing Industry during New Product Development

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Abstract

Continuous improvement or KAIZEN denotes doing right things in a better way and to make it an ongoing improvement process to achieve results in productivity enhancement in any Industry especially manufacturing. Hence, it's crucial to incorporate effective productivity improvement methods in order to ensure productivity growth and prosperity of individuals and organizations as a whole. The principle aim of the project is to initiate and understand the concepts of continuous productivity improvement, diverse techniques & methods involved, Time & work study and subsequent relation with productivity improvement.

Productivity is the relation between output (which is in this case actual accrued production) and input (here it refers to investment of resources & time consumed for the accrued production) i.e a proportion of the same. It is numerical relationship which denotes production in numerator (i.e what has to be produced) & resources in denominator (what has to be spent to produce). Productivity improvement is reduction in wastage of various resources involved such as manpower, material, machine, money, minutes, method & measurement etc. Achieving better production by utilization of same available resources such as labour, land, money, machine, materials or time by adopting concepts of lean management results into leaner and more profitable business value chain.

Most of the leading manufacturers across the globe thrive and survive on this philosophy and thus it's a key thought of modern management & technology which results in innovations in this sector. Innovations could be localized i.e plant expertise or could be institutionalized i.e by leading research or innovation agencies. Most of the manufacturing units in India have rich localized tacit knowledge pool and the said is being used to streamline, systematize & further innovate to improve the entire business value chain. The scope of this piece shall be in bearings industry manufacturing and development process and thus providing an insight of application of productivity improvement principles in the same.

Keywords: Cycle Time Reduction, Idle Time, Productivity, Bottleneck, Line Balancing, Bearing Industry, Grinding Allowance, Manpower Efficiency Improvement, New Product Development.

Introduction

In this piece we'd be focusing on bearings manufacturing productivity improvement. Bearings (Ball & Roller bearings) are precision products which are being used to achieve antifriction in various automotive, agriculture and Industrial applications. This industry is crucial to economy as bearing is one of the very few precision products which are being utilized in such a scale. Any KAIZEN or productivity improvement exercise being undertaken shall be affecting the industry as a whole considering such a nature of this product.

In bearings manufacturing the involved heat treatment, grinding & assembly process are parts of this process where grinding & assembly are based upon single piece flow concept where different operation are performed on different machines in a sequential way. The part is processed on every machine and move to next station for further processing till end of the line packaging of the bearing. The work piece flow on each and every station by automatic running conveyor system.

In such sequential process of manufacturing, cycle time of each process plays an essential role in parts cost and productivity. Any reduction in Cycle time has appeared as a basic element in the master plan of new product development. Actually, many companies now accept that their potential to launch new products speedily and efficiently is necessary to their long-term existence and profitability. In most of the industries, reduction in cycle time of new product development involves a notable change in development process thoughts from the standardized development processes.

This research is focused on bearing industry grinding lines for new product development cycle time reduction by line balancing. The different sizes of Inner and Outer races are set on grinding lines. The assistance to bottleneck area will considerable improve the cycle time results in productivity improvement.

In bearing development if grinding line is not balanced than it is a direct wastage of resources and time consuming product development with low efficiency this affecting the value chain proposition of the industry. In the grinding line if the cycle time of one process is higher then it will affect the complete process cycle time, if the line balancing is done in grinding line it will result in smooth functioning of line without bottleneck.

Productivity contributes in the wealth and prosperity of society as a whole and the same has been exhibited in the famous quote of Nobel Prize Laureate Paul Krugman:

"Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker."

Krugman's quote denotes that productivity depends upon the output of labour. The limitation with this definition is that it only considers productivity to an efficiency measure, hence it either preconceives (or, ignores) effectiveness. In case the resources input and time are considered constant, it establishes direct proportion between respective productions and considers that as an efficiency measure. Now, if market need is limited and there is no scope of higher consumption, this conclusion stands null and void. In order to understand productivity in totality, we should create a link between supply & demand.

Industry runs on principle of demand and supply and especially in case of manufacturing industry, the resources & investments are aligned for future productivities and profitability. Paucity of proper resources make it extremely important & at the same difficult to achieve better production in available resources. The constraints are identified & rectified on a regular basis however, this cannot be fully eradicated as constraints are always there in any process and they are the part of process.

According to T Netland, there are 5 Basic directives of productivity improvement which are applicable in today's era of industrial revolution 4.0: -

Directive 1. Value delivery for the customer

Doing first time right & repeating it by achieving every time right is the crux to deliver value to the customer. Here, the process established should be firstly effective and then efficient. It means, we must start with a clear customer centricity. Now, customer centricity and its relationship with productivity is summed up by the Concept of quality assurance. It means, deliverables must be as per the customer conformance. Any non-conformity shall result into poor value delivery to end customer.

Directive 2. Measures to control process

Processes or resources must not be overloaded. Any process is successful to extent it discounts for the resources it incorporates. As per Queuing theory, its mathematically proven that when utilization gets nearer to 100%, the entropy in system grows exponentially. The principle measure here is to optimize the utilization and not exploiting the resources. The exploitation must be avoided for firstly, manpower and then for other resources. Process control could be achieved by technology. Digitalization and automation could help in De-bottlenecking but the maintenance practices should be robust.

Directive 3. Process Synchronization within a system

Process synchronization required system perspective. The variation in production process kills productivity and the same must be avoided. Strategic and dysfunctional variation must be differentiated and latter must be sought eliminated. The strategic variation gives edge over competition and must be kept. There are many techniques which help to synchronize the processes such as standardization, JIT (Just in Time) logistics, manufacturing modularity and assembly optimization.

Directive 4. Reduction in process yield time

Process Non – Value addition activities must be eliminated in order to reduce the process yield time without compromising on above three directives. Increase in throughput times shall be resulting into better productivities.

Directive 5. Kaizen – Continuous Improvements

There are two principles behind this directive, firstly, the system is never perfect and there is always a scope of improvement to achieve better operational efficiency and secondly, the business environment is dynamic which drives organization to go for business level disruptions. Disruption may include analogous changes in existing business process or radical changes in technology or organizational innovation front. Developing an organization culture to be compatible with analogues changes or radical reforms is important to achieve continuous improvements in productivity.

The current project has been taken to study production process of a high production line in Taper Roller Bearing division at NEI Limited, Jaipur plant and it has been observed that there is a scope of improvement in productivity of the said production line thus achieving better operational efficiency.

The operational efficiency of any manufacturing process or sub-process depends upon two factors i.e Men & Machine. This project has a

scope of working and improving in both aspects of the operation.

Focus has been given on machine bottlenecks (inherent machine capabilities and improvement in the same) and manpower wastages (skills and work-time gaps identification and suggesting measures to overcome the same)

Below are the salient points of this project

1. The principle aim of this project is to increase the production on T-4 grinding line by optimizing productivity. If the level of output is increased in time available, productivity will increase.
2. Cycle time is being used as the tool to measure each workstation's productivity. The workstation which takes the longest cycle time will be the bottleneck & hence treated as a critical process. This will decide the overall output in terms of units. So the productivity can be increased only if we de-bottleneck the critical process.
3. Manpower management – Work time study has been done and its implied that running time of machine improvement could be achieved from current levels to better levels hence increasing productivity on manpower utilization.

In addition to productivity management by adopting lean principles, it's quite essential to consider theory of constraints while working on the said project.

The constraints could be defined as the factors preventing a system from achieving its designated goals. There can be many constraints but the basic principle within Theory of Constraints is that there are only few constraints within any given system. They might be internal or external to the system. The internal constraint are exposed when the demands are higher than what the system can deliver. In this case the focus of the organization should be on identification by doing why-why analysis and following the five steps to eradicate or at least take a intermittent measure for prevention. External Constraint are exposed when the system produces additional than what market will consume. In this case, the organization must devise mechanisms for additional demand creation for the desired products and services.

Major Internal Constraints

Machines

Current utilization pattern of the machine limits the ability of the system to produce more deliverables.

Manpower

Shortage of qualified manpower and lack of skills in existing set of people limits the system. Mental limitations held by people causes behavioural issues which result into constraints.

Strategy

Organization Strategy & its lack of flexibility prevents the system from adapting as per market dynamics limits the creation of revenues.

Overcoming Constraints

Any constraint which is no longer the limiting factor of the system could be termed as overcame i.e by adopting ways of productivity management. Once the constraint has been overcome, new limiting factors arise out of the system which result into further constraint creation. It may be the part of the system or may be external to the system

Operation efficiency being coupled with managing system constraints shall be instrumental in getting maximum productivity out of the current set of operations without making much changes.

Review of Literature

Literature review been conducted with two major objectives (a) understand work and approaches taken by other organizations (b) understand the gaps in current work to enhance the effectiveness of solution. Details of literature review as follows

Work and Approach

Since Customer requires better quality, shorter lead time, improved service level and optimum price, organizations adopt continuous improvement in quality & productivity to survive the highly dynamic & competitive market. To achieve the same, line balancing approach to improve the productivity is essential.

1. Zupan H. et al. (2015), maximizing production by utilizing Line Balancing and discrete event simulation approach. Results of combination of line balancing and process optimization will increase the rate of production significantly. In order to do this, process optimization by utilizing improved simulation model and its comparison with existing production line is carried out. Depending upon the same, research results are compiled, analyzed and processed thus concluding the improvement in productivity.
2. Jafri Mohd Rohani et al. (2014), Upon utilizing VSM (Value Stream Mapping), they identified the current process flow of color industry, identified & eliminated the wastages by developing a CFT (Cross Functional Team) which has contributed in Product Selection, conceptual design and time frame formulation through time calculation thus achieving lean calculation.
3. Sandip K. Kumbhar et al. (2014), Process, Work & Motion analysis studied and time for calculation at the rate at which the product is required before and after the KAIZEN. Operation Cost has been reduced considerably. Cycle timr study optimization is helpful for low cost automation and the activity has been bench marked at industry production improvement level.
4. Juthamas Choomlucksanaa et al. (2015), worked on improving work efficiency in manufacturing sheet metal stamping process by adopting lean manufacturing. Lean and Other Improvement tools such as Poka-Yoke, 5S and visual controls were applied for improving the production process efficiency and identifying opportunities for waste reduction (Non Value added activities like deburring& polishing have been addressed as quickly as possible).
5. Khalil A El-Namrouty et al. (2012), probed the current position of waste eradication in Manufacturing companies in GAZA Strip, its interrelation in reduction of production cost has been studied.

6. Also, Lean thought process has been aimed to promote through studying 7 wastes which were targeted. WRM (Wastes Relations Matrix) was implemented to analyze the inter-effects and impacts between 7 wastes.
7. PritiKhadse et al. (2003), studied Lean Manufacturing and identifying critical lean manufacturing factors responsible in Indian manufacturing sector How to incorporate these lean manufacturing factors into a framework, which can provide the current status of lean practices. Identification of hindrances and profits of lean manufacturing in industries has been done.
8. Aasheet Kumar et al. (2010), has utilized the approaches to improve the wire Harness productivity on the assembly line dedicated for automobile business. The calculation for balance rate before and after the improvements were done to show the manpower reduction and it inverse proportion with production output. In addition to the same, line balancing and proper line loading are the active areas of optimization research in Manufacturing & operations management.
9. Silva et al. (2012), Due to removal of multi Fiber agreement in 2005, clothing industry in Sri Lanka faced considerable changes. Delivery of low cost and high quality garments in stringent timelines became an utmost necessity. In 2008, clothing industry suffered a setback due to increase in demand of low cost garments. Upon adopting Lean principles in Local Industry, Industry was able to perform better.

Knowledge Gained from Literature Review

1. Optimizing of assembly lines by applying the line balancing concepts and discrete event simulation approach
2. Process, Work & Motion analysis studied and before and after effects of the KAIZEN analysed.
3. Lean and Other Improvement tools such as Poka-Yoke, 5S and visual controls can be applied for improving the production process efficiency and identifying opportunities for waste reduction
4. Incorporation of lean manufacturing factors into a framework to provide the current status of lean practices. Identification of hindrances and profits of lean manufacturing in industries could be identified for further improvements.

Gaps in Current Research Work

Literature review suggested that the researches are mainly focused on assembly and manufacturing lines, cannot be implemented in bearing industry grinding lines because of following gaps.

1. Available Research works are principally on manufacturing lines.
2. Available Research work are principally on assembly lines.
3. It doesn't deal with specifically bearing industry and bearing manufacturing sub-processes such as Heat treatment, Grinding, Honing, Bearing Assembly and inspection.
4. There is no literature review is available on bearing grinding line productivity improvement.

Objectives of Case Study

To increase the production on T-4 grinding line by optimizing 4 M's of manufacturing during regular production and new product development i.e.

Man

Workforce (Skilled/Unskilled) which is required to carry out defined set of operations to produce the parts.

Methods

Process or sub process from which a product has to pass before it is ready to be delivered as a final product to a customer. Consistent & controlled procedures must be applied to perform value added work The machine should be able to verify the process each part or assembly being processed is correct and meets the quality parameters of the product.

Machines

Each rig or fixture in the production line must be able to perform the desired function with precision & reliability. Manufacturing such machines which are robust, adaptable for ramp-up, self-diagnosing, having process inspections and mistake proofing while manufacturing shall be the key to achieve the FTR (First Time Right) & ETR (Every Time Right).

Materials

While considering for productivity improvement, automation in incoming and outgoing material flows should be considered as an effective and error proof solution. Making equipment which facilitate ease in material flow can pay rich dividends in the process.

"By analyzing aforementioned aspects, it was a clear that the subjected manufacturing line has got several processes, sub-processes and workstations which require analysis and process optimization by identifying & removing gaps and wastages."

Methodology and Experimental Work

The author have proposed methodology for identifying bottleneck operation and any new initiative in the organization need openness for the change. The changing conventional way of doing things.

Selecting the research area:

1. Understanding manufacturing process of Taper Roller Bearing (which has been taken as a pareto factor for this project)
2. Determining Area of potential research, grinding operation (identified as bottleneck operation)

Formulating Research Aim, Objectives and Research Questions or Developing Hypotheses.

Productivity Improvement

1. Cycle time reduction by line balancing.
2. Increasing manpower productivity.
3. Increase / optimize the automation.

Hypothesis

1. Since this line is fully automated from grinding to assembly increase in automation stands null and void.
2. Natural hypothesis in this case shall be "cycle time reduction by line balancing and by improving manpower productivity".

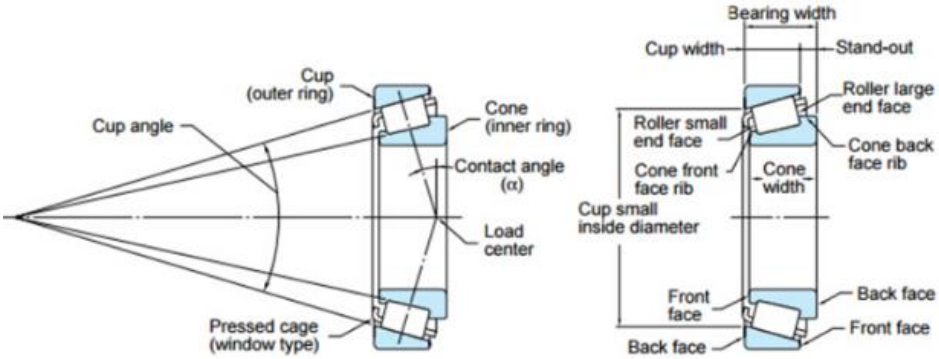
Selecting Methods of Data Collection

Information Collection – Primary data collection by visiting subjected line in person and recording data of

Product – Type of Product and Components

The subjected line is being utilized to Manufacture Single Row Taper roller bearings, Tapered roller bearings are line contact bearings which are having rollers as rotating elements Races are Cup & Cone) which are being used in several Automotive & Industrial applications. The manufactured size on the subjected batch is TRB 31594/31520 .The said material has been selected for analysis as there are issues and opportunities available in the said part for productivity improvement.

Fig - 1



Process – Process Heads / Flow Involved In Entire Value Chain

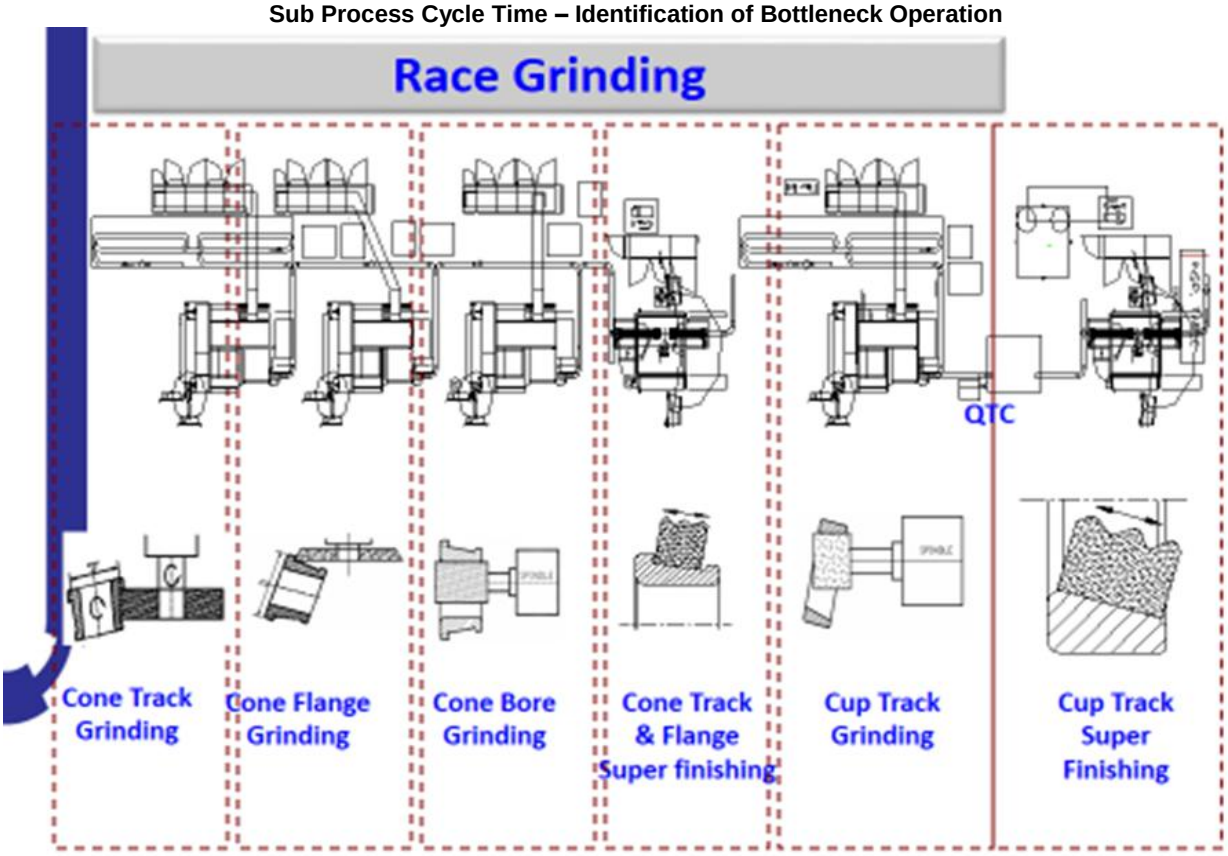
The process here means manufacturing process of the Subjected Taper roller bearing on the identified grinding line. Process starts from Alloy Steel bars/Tube (material grade SUJ2/SAE52100) being converted into form for races (Cup & Cone) of specific sizes, Wire Rod being converted into Rollers & Sheet Metal strips converted into retainer (which is being bought as a finished component). Races & Rollers are heat treated, grounded, Honed & super-finished to achieve surface finishing.

Process Flow of Race Grinding

Race grinding is a process to convert rough turned races into finished races to be assembled into a bearing which can establish point/line contact with the rolling element (in this case Tapered rollers) to achieve antifriction properties. Race Grinding has got several sub processes as depicted in below chart.

Fig.-2

Sub Process Cycle Time – Identification of Bottleneck Operation



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Challenges and Solution Approaches

Cycle time is an important factor for grinding line balancing in bearing industry. Cycle time is the time taken for processing the product on machine and loading/ unloading time.

Cycle time = Total Operation time (Processing time + Loading/ unloading time)/ Product produced (Quantity).

Cycle time optimization of bottleneck operation for increasing productivity of line. Cycle time optimization is done by following:

1. Eliminating non value added activity from process
2. Optimization of grinding allowances of bottleneck operation after study.
3. Grinding wheel / honing stone specifications up-gradation.
4. New Generation wheel/ honing stone trial

Any new initiative in the organization need openness for the change. During research of this paper, it came across many challenges which need to be addressed to have good line balancing initiative to achieve significant productivity improvement.

Challenges

Major challenges faced are as follows:

1. Currently, design activities are more driven by set of design rules in the bearing design office. Challenges to reduce grinding allowances against set design rules.
2. Loss of reduce grinding allowance experimental lot in case black material occur.
3. Loss of one shift production while trial of experimental lot.
4. Published research is available for reference purpose but this research is not in the context of particular organization. Typically, Grinding allowance reduction project needs execute in very small organizational boundaries and all the grinding allowance new rules to be generated during case study.
5. Design process rules are highly subjected to design engineers' expertise, experience and availability of correct data to engineers. Challenge is to reduce grinding allowance and effort requirement to measure the improvement once the grinding allowance reduction initiative implemented.

The above challenges were major challenges and needs approval from research and development department senior officials.

Solution Approach

As a first step to solution, study of cycle time of each operation of grinding line and list down the cycle time of all operations. Bottleneck operation identified.

Cycle Time								
Grinding Line	Bearing No.	Cone Track grinding	Cone Flange grinding	Cone Bore grinding	Cone Track S.F.	Cup Track grinding	Cup Track S.F.	Bottleneck operation Cup Track grinding
Taper Bearing	31594/31520	17.90	17.65	16.36	15.23	24.20	18.60	24.20

Bottleneck operation identified "Cup track grinding".

After Brain storming session conducted and prioritization done after detailed group discussion and data analysis. Cause of High Cycle Time is High Grinding Allowance observed in Cup Track after Heat Treatment.

Before

Turning Size: 57.61 +/- 0.05, Finish Size: 58.114 0/- 0.054, GA (mm) : 0.300 TO 0.400, and actual GA (mm) : 0.550 to .650.

Data Collection of Selected Cup from Existing Drawing after Heat Treatment

GA in 31520 Cup Bore					
S.NO	Avg Side A	OOR Side A	Avg Side B	OOR Side B	Taper
Max	-450	100	-450	110	100
Min	-530	10	-650	10	0

Team of manufacturing, R&D and QA has decided to reduce grinding allowance in track.

Proposed Action

100 Micron Grinding Allowance reduces in Cup track and 5000 Pcs procured as per experimental drawing.

Experimental drawing having revised GA and that revised GA is coming based on the G.A. after heat treatment from existing drawing.

After

Turning Size: 57.71 +/- 0.05, Finish Size: 58.114 0 /- 0.054, GA (mm): 0.200 to 0.300 actual GA (mm): 0. 350 to 0.430

Check input material from experimental drawing (Turing, after heat treatment and after face grinding)

GA in 31520 Cup Bore					
S.NO	Avg Side A	OOR Side A	Avg Side B	OOR Side B	Taper
Max	-350	110	-355	100	50
Min	-425	20	-430	10	0

Procurement of Experimental lot by logistic and information sharing by RM inspection, Pilot lot of 5000 pcs. procured and trial conducted.

Perform cycle time study of cup track grinding process

31520 track Grinding allowance reduction batch run successfully on grinding line and cycle time achieved is 22.0 seconds.

Results and Impacts

The data presented in this paper is collected from bearing manufacturing industry's taper roller bearing grinding line. Upon the identification of bottleneck, going though complete process cycle & manpower utilization pattern, following results have

accrued and put up for discussion in order to improve upon productivity.

1. Line balancing by GA reduction in Cup track grinding machine is improving overall cycle by 2.2 seconds thus giving 10000 numbers additionally per month.
2. Line loss due to manpower inefficiency was about 10080 numbers which can be recovered by adopting manpower optimization measures.
3. Total additional production expected annually (approximately) 2.4 lac bearing without any additional investment/efforts/resources.
4. Productivity Improvement by line balancing and manpower optimization measures.

Conclusion

It is evident from the current case study that Productivity improvement in manufacturing is only successful when it is being adopted utilizing concepts of TOC (Theory of Constraints) which is a technique that provides insights into philosophy of operational efficiency. Process limitations could be overcome by having clear identification of Gaps and thus removing those gaps through 5 rules of productivity improvement.

Overall 22.2% productivity improved due to line balancing by Grinding allowance reduction in Cup track grinding machine and improving line loss due to manpower inefficacy.

We've seen that a net impact of about 2.4 Lac units in positive side happened without applying additional investment signify the applicability of said set of rules and hence hypothesis of de-bottlenecking by utilizing lean principles stands true.

Suggestions

Same line balancing approach for productivity improvement is to be adopted while developing new products in bearing manufacturing industry in future.

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