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Research Article

Cycle Time Reduction of PCF Gearbox using Total Productive Maintenance (TPM) Approach

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Abstract

In this article, we would like to review an incredibly effective, yet underutilized approach: cycle time reduction. We will also describe a demonstrated cycle time reduction methodology and those factors we believe key to the achieving breakthrough results. With the help of Total Productive Maintenance (TPM) approach cycle time reduction of the PCF gear assembly will be reduced using 5S methodology and other pillars the assembly would be refined in appropriate manner. 5S, Kobestsu Kaizen (KK), JishuHozen (KK), Safety Healthy and Environment (SHE) and Education and Training (E&T) Pillars will be implemented in procedure systematic manner to reduce the cycle time reduction of PCF gear assembly and improve upon the process of the assembly procedure.

Keywords: *Cycle Time Reduction, Productivity, Maintenance, Total Productive Maintenance.*

1. Introduction

The product on which the study was conducted for the cycle time reduction is the planetary gear box (PCF). It is a job shop type product to be assembled. The PCF gear box is shown in the following figure.

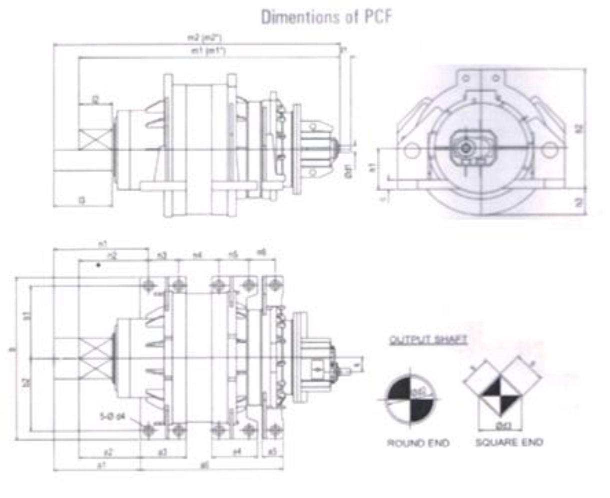

Fig 1PCF Gearbox

The PCF gearbox are mainly used in sugar mill drives, mining industries. It's a heavy duty planetary gearbox which is also called PCF gearbox. The gearbox has order twice a year means it's a seasonal product

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2. Problem Identification

The PCF gearbox is assembled in the HELICAL P division of the organization. The process was not well defined and the losses according to the TPM was to be reduced in manner to reduce the cycle time reduction.
In assembly area the TPM approach was to be implemented as it was implemented in the manufacturing sector so it was affecting the assembly operation.

3. Literature Review

Total Productive Maintenance (TPM) is a unique Japanese philosophy, which has been developed based on the base productive maintenance concepts and methodologies. M/s Nippon Denso Co. Ltd Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971, first introduced Total Productive Maintenance concept (NilmaniShahu et al, 2013).

After Second World War Japanese industries realized that, company cannot produce good quality products with poor maintenance system of equipment and cannot stay in global world competitive market. The Japanese companies already adopted the U.S.A. management policy and manufacturing technologies as per their suitability or as per requirement. For the effective maintenance system, Japanese industries adopted U.S.A. preventive maintenance policy in 1951.After that they imported preventive maintenance and reliability of maintenance principles (Venkatesh J, 2007).

Total productive maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day to-day activities involving total workforce (I.P.S.Ahuja et al, 2008)

The manufacturing industry has experienced an unprecedented degree of change in the last three decades, involving drastic changes in management approaches, product and process technologies, customer expectations, supplier attitudes, as well as competitive behavior (I.P.S.Ahuja et al, 2006).

4. Methodology

4.1 Total Productive Maintenance (TPM)

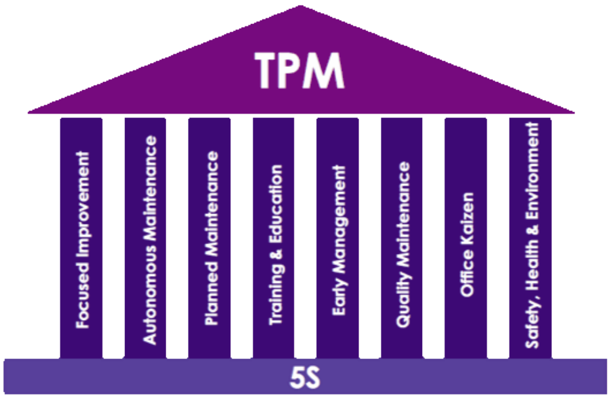

Fig 2 Eight Pillars of TPM

4.2 Objective of TPM

TPM was evolved around certain objectives

- Avoid wastage in quickly changing economic environment.
- Producing goods without reducing the product quality.
- Reduce all costs.
- Produce a low batch quality at the earliest possible time.
- Goods sent to the customers must be non-defective.

4.3 Pillars of TPM

The Japan Institute of Plant Maintenance(JIPM) propose introduced the TPM program is based on the implementation of a series 8 pillars of TPM in a systematic way to optimize plant and equipment efficiency and effectiveness by develop perfect relationship between man and equipment. The diagram below represents a common structure of TPM pillars.

5. Data Collection

5.1 Process of PCF Gear Assembly

Table 1 Assembly Process of PCF Gear Assembly

Sr. No.	Designation
1	Preparation Of Assembly components
2	Output shaft assembly
3	Input shaft assembly
4	Housing Assembly
5	Shrinking
6	Main assembly
7	FLS piping

5.2 Strategy for Maintenance System

- Define the cleaning of plant and make a schedule of plant cleaning.
- Bearing, impeller, fasteners, sleeves, stock are maintained as per their life and stored in plant store.
- Unnecessary, unwanted materials are removed from plant
- Maintenance replaces spare parts store are arranged as per similar group.
- Define role of operator and worker and it is based on rotating policy as per day wise and making a monthly schedule for worker (Daily monitoring).
- Define TPM quality circle and discussed between workers
- Provide a training for improve maintenance quality.
- Provide training for change the old culture of maintenance culture.
- Arrange the TPM circle meeting as per schedule.
- Maintain the maintenance record in a computerized maintenance management¬ system.
- Use of different TPM maintenance analysis tools.
- Implement 5S.
- Implement Total Productive Maintenance. (KK, JH, SHE, and E&T pillars)

5.3 Total Maintenance Department staff

Table 2 Total Maintenance Department staff

Sr. No.	Designation	Total Numbers.
1	Supervisors	10
2	Technician	8
3	Storekeeper	2
4	Senior Engineer	2
5	Quality Engineer	1
Total = 23		

These is the team develop upon to do the project. With the team developed brainstorming sessions, meetings, training schedules were made.

5.4 Process Flow Chart of PCF Gearbox

The Existing Process Flow Chart of the PCF gearbox assembly is shown below

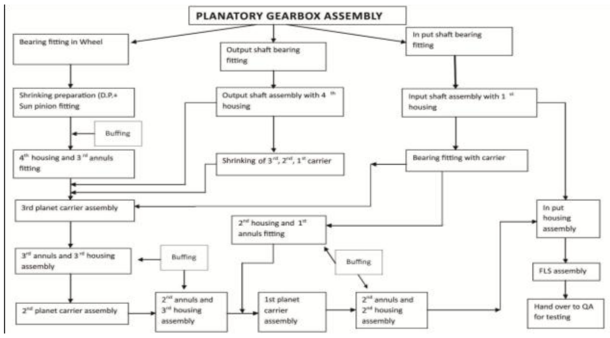

Fig 3 Existing process flowchart

5.5 Time Data Collection

Before implementation of TPM time data was collected of the PCF Gearbox according to the parts assembled.

Table 3 Time Study of Housing 1 Annulus 2

Elecon engineering co. Ltd. Anand Helical p division (PCF gearbox) Start time 8:45 AM			
Serial No.	Part	Number of Man	End time
1	Housing Body 1	1	8:50
2	Housing Body Buffing	2	9:30
3	Inspection	1	9:40
4	Tea Break		10:00
5	Annulus 2	1	10:10
6	Annulus 2 Buffing	2	10:45
7	Inspection	2	10:55
8	Transporting Annulus to housing	1	11:00
9	Fitting Of Annulus and Housing	2	11:15
10	Inspection	1	11:20
11	Gone to take hexagonal bolts*18	1	11:30
12	Setting all things		11:45
13	Lunch Break		12:35
14	Fitting Hexagonal bolts	2	12:50
15	Inspection	2	1:15
16	Housing 1 and annulus 2 assembly completed		1:20
17	Transporting assembly to rest area	1	1:30

The Above data is of Housing 1 and Annulus 2. Likewise for Housing 2 and Annulus 3. Housing 3 and Annulus 4, Carrier Wheel 1,2,3,4 and 5 and Fast Lubrication System (FLS) were collected.

Table 4 Total Cycle time of PCF Gear Assembly

Sr. No.	Designation	Cycle time Data
1	Preparation Of Assembly components	1220
2	Output shaft assembly	197
3	Input shaft assembly	150
4	Housing Assembly	150
5	Shrinking	780
6	Main assembly	1500
7	FLS piping	300
Total=4297 minutes		

5.6 Flow Process Charts (FPC)

The flow process chart in industrial engineering is a graphical and symbolic representation of the processing activities performed on the work piece or the product assembled.

Table 5 FPC Symbols

Sr. No.	Tasks	Symbol	Operations
1	Operation		To change the physical or chemical characteristics of the material
2	Inspection		To check the quality or the quantity of the material
3	Transportation		Transporting the material from one place to another
4	Delay		When material cannot go to the next activity
5	Storage		When the material is kept in a safe location

As the time data was collected FPC of similar were made to know the distance travelled and operations made in the assembly operation of the PCF gearbox assembly, which is shown below.

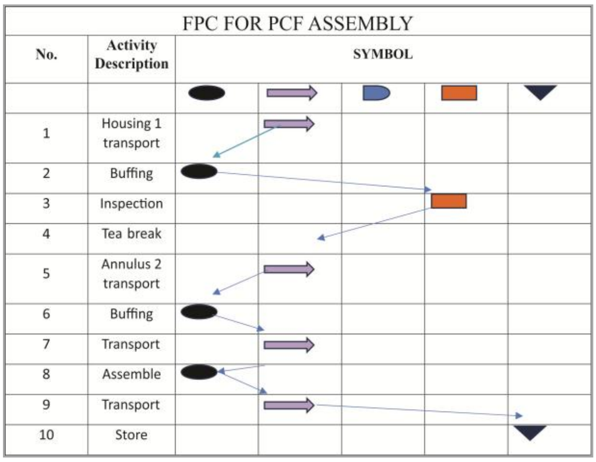

Fig 4 FPC for Housing 1 Annulus 2

Similarly for other assembly components the FPC were drawn and the following results were generated.

Table 6 Result of FPC before TPM

Names	Before TPM
Total Operations	32
Total Distance Travelled (metres)	74 metres
Total Inspections	12

After the data taken the total assembly time and FPC the following result was generated based on the data collected in the HELICAL P assembly unit of the PCF gearbox.

Table 7 Assembly of PCF data

Assembly Data		
	Total minutes	% of total
Assembly Time	4297	66%
Loss Time	300	5%
Authorized Brake/lunch	1920	29%
Total available time	6517	100%

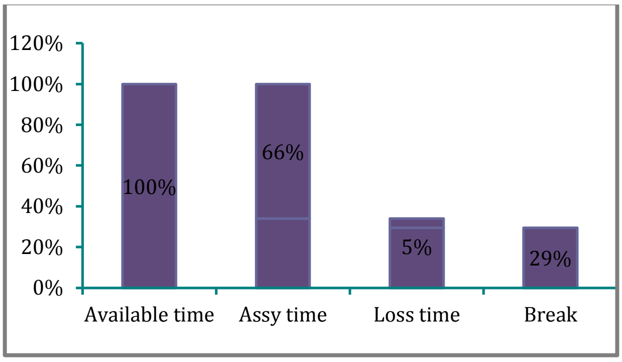

Fig 5 Assembly Data shown in graph

5.75S Implementation in Helical P Assembly

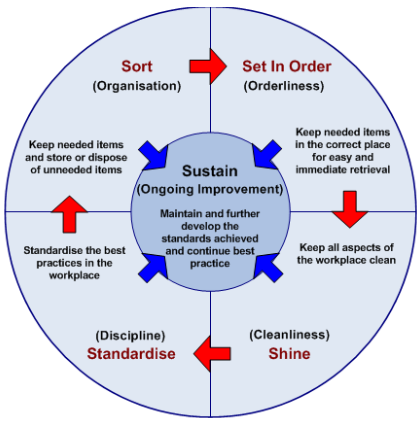

Fig 6 5S Methodology for Plant

As per TPM guideline, 5S is the barometer of management. According this guide line 5S's basic requirement is follow the phosphoric plant.

Unnecessary or unwanted used spare parts, pipes etc. Are removed from the plant but not on the way of 5S.

Suggest and implement cleaning shift schedule. Shift schedule is making under guideline of production department and it is as per industry suitability. Cleaning shift schedule is mention in following table:

For the different S in the 5S which are **S1-Sort, S2-Straighten, S3- Shine, S4- Standardize, S5- Sustain** check sheets were made to implement the 5S methodology.

Table 8 Check sheet for S1-SORT

S1-Sort		
1	Components, materials & parts.	Only the current levels of inventory in the area is needed for the work at hand. Scrap and rework items are placed in clearly marked containers.
2	Machines, benches, cabinets & furniture.	Only the necessary items to perform the work at hand are located in the area. There are no unneeded machines, tools or furniture in the area.
3	Tools, fixtures & other equipment.	All tools, fixtures and jigs in the area are used on a regular basis. Any items that are used less than once a day, are stored out of the way.
4	Bulletin Boards	No outdated, torn or soiled announcements are displayed. All bulletins are arranged in a straight and neat manner.
5	First Impression Overall	Your general impression should tell you this is the best you have seen for a manufacturing environment.

Likewise for S2, S3 S4 and S5 check sheet were made and from that the unsafe conditions for the equipment's in the assembly floor was made shown below

Table 9 Unsafe conditions of the Equipment's

Unsafe Equipment's				
Sr.No.	Name Of Section	Name of Equipment	Unsafe Side	Remarks
1	Lifting Devices	Lifting Devices	On floor	Accidents Happens
2	Heating tank controls	Controls	Open	Accidents Happens
3	Tools & tackles	Unplanned	Not Visible	Takes Time
4	Pipes	Pipes	On floor	Accidents Happens

Afterwards photographs were taken of the before and after condition after implementation of the 5S methodology

Fig 9 Lifting devices

Fig 10 Heating Tank

Fig 11 Tools & Tackles Photo

5.8 Autonomous Pillar

Autonomous pillar was implemented, in these pillar the different types of losses were recognized and Pareto charts were made and the losses were reduced by taking month wise maintenance data which are shown below.

Table 10 ABC Analysis of types of losses occurring

Type	Types of Losses
A	Management Loss
1	Waiting for material
2	Waiting for drawing and instruction
3	Waiting for crane
4	Waiting for inspection
5	Waiting for manpower
6	waiting during Inspection
7	waiting during Design problem
8	Extra work
9	No Space In Assembly
10	Equipment Failure
11	Rework QA/shop
B	Motion Losses
1	Unnecessary Movement
2	Movement for tools and Materials
C	Measurement And Adjustment loss
1	End clearance adjustment
2	Assembly re-work

According to different losses data was collected and Pareto chart was made.

Table11 Management loss data

Management Loss	Time (Min)	Time (Hrs)	Percentage of total	Cumulative
Waiting for raw material	29665	494	38%	38%
Rework	17818	297	23%	60%
Machine development	15621	260	20%	80%
Waiting for instruction	10146	169	13%	93%
Waiting for man power	3528	59	4%	97%
Extra work	2115	35	3%	100%
Total	78893	1315	100%	

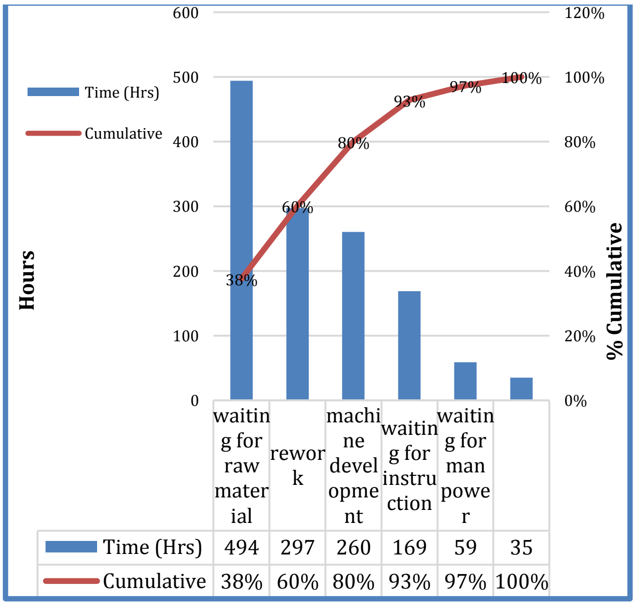

Fig 11 Pareto of Management loss data

5.9 Kobetsu Kaizen Pillar

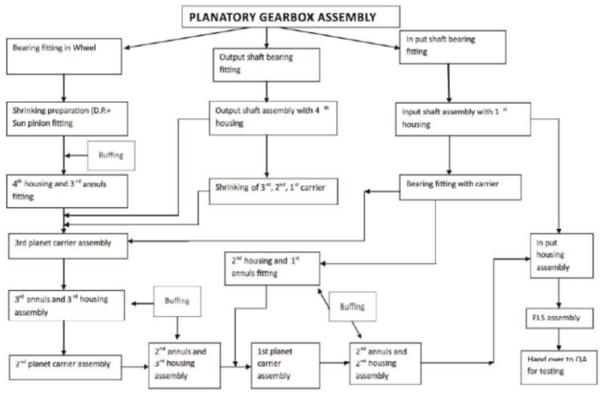

Fig 12 Existing Process flow chart

Breakdown data were noted month wise for the Helical P assembly data as shown below:
Month wise breakdown data were noted:

Table 12 Before and after Breakdown data

Before TPM		After TPM	
Month	Downtime	Month	Downtime
October	35.15	January	27.15
November	37.20	February	24.65
December	37.20	March	26.95
Total Downtime= 109.55 hr		Total Downtime= 78.75 hr.	

After the breakdown data was taken and the KK and JH pillar implementation the losses which were waiting for material and motion losses were reduced which were causing problem

Table 13 Revises Management loss data

Management Loss	Time (Min)	Time (Hrs)	% of total	Cumulative
Measurement and Adjustment Lost	25673	428	35%	35%
Motion loss	17356	289	24%	59%
Waiting for man	15737	262	22%	81%
Waiting for material	8357	139	11%	92%
Equipment failure loss	3528	59	4%	97%
Extra work	2115	35	3%	100%
Total	**72766**	**1213**	100%	

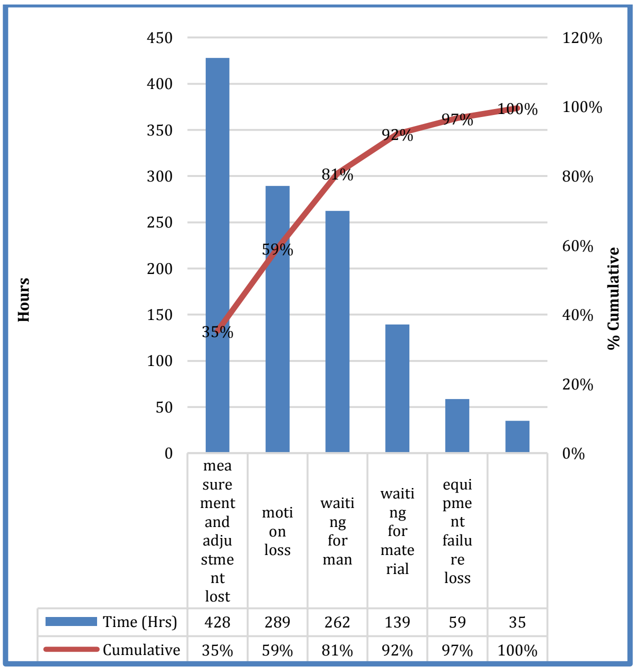

Fig 12 Revised Pareto Chart

In the above we can see that waiting of material is been reduced and equipment failure loss is been reduced by the Kobetsu Kaizen Pillar.

5.10 Safety, Health and Environment Pillar

Safety, Health and Environment (SHE) is the final TPM pillar and implements a methodology to drive towards the achievement of zero accidents. It is important to note that this is not just safety related but covers zero accidents, zero overburden (physical and mental stress and strain on employees) and zero pollution.

Table 14 SHE PILLAR for Assembly Area

Background	Aim
Mostly cause of accident is found due to unsafe practices	To enhance awareness towards safety for zero accidents
A belief that safety is managements responsibility	To make all responsibility for safety
Management/ Government takes care of environment	Everybody is responsible for environment for pollution prevention

5.11Education and Training Pillar

Training and Education is the pillar of TPM. It ensures that staff is trained in the skills identified as essential both for their personal development and for the successful deployment of TPM in line with the organization's goals and objectives.

Table 15 Education and training pillar

Background	Aim
Unsystematic training Method	To develop multi skill operator
No scientific method for skill & knowledge analysis	To upgrade skill of operator
Unsystematic measures for breakdowns, accidents and defects	Zero breakdown , defect and accident

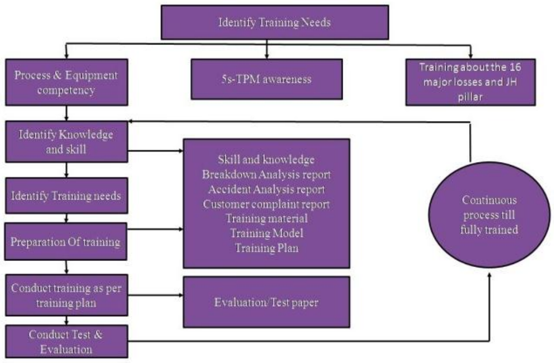

Fig 13 Strategy for Education and training pillar

5.11 Overall Equipment Efficiency Calculations (OEE)

Shift information

Shift length: 8 hr, Total shift minutes: 480 minutes.
Lunchtime per shift: 30 minutes.
Total shift/day: 3(production),
Short breaks per shift: 2
Break time: 15 minutes; Total break Time: 30 minutes
Other planned down time (Preventive Maintenance): 41 hr (2460 minute)
Planned down time per shift: 18.73/shift. (As per preventive maintenance)
Total Unplanned downtime: 109.55 hr
Unplanned downtime/shift: 67.73 minutes
Production information
Total production = 250
Planned production time = shift minutes - (Break +Lunch) =480-(60) = 420 minutes

Ideal run rate = <u>Annual demand</u>

12 months x30 days/month x3shift/day x 8 hr/shift
= 500
12x30x3x8
= 57.73 Gears Produced

Expected produced = Ideal Run Rate X Planned Production Time
= 57.73x7
= 404.11

Now Net loss = (Total production time-Total shutdown time)
= 4297-(192.25+288)
= 3816.75

Availability of production: = (Net loss /total production time) X100

= 3816.75/4297*100
= 88.82%

Performance Rate = Average production for a given time X100
Maximum production for that time
= 220/225*100
= **97.73%**

Quality Rate = Good production x100
Total Production
= **230/250*100**
= **93%**

OEE = Availability rate x performance rate x Quality rate
= 88.82 % * 97.73 % * 93%
= 80.72 %

Revised OEE Calculation:
Total Production = 230
Total Unplanned downtime =78.75
Now Net loss = (Total production time-Total shutdown time)
= **2587-78.75**
= **2508.25**
Availability of production. = (Net loss /total production time) X 100
= 2508.25/2587*100
= 96.95%

Performance Rate = Average production for a given time X100
Maximum production for that time
= 235/240*100
= 96.95%

Quality Rate = Good Production x100
Total production
= 235/250*100
= 94%

OEE = Availability rate x performance rate x Quality rate
= 96.95%* 96.95%*94%
= 89.73%

Table 16 Before and After Implementation of TPM

Before TPM		After TPM	
Availability rate	88.82 %	Availability rate	96.95 %
Performance rate	97.73 %	Performance rate	96.95 %
Quality rate	93 %	Quality rate	94 %
OEE	80.73 %	OEE	89.73%

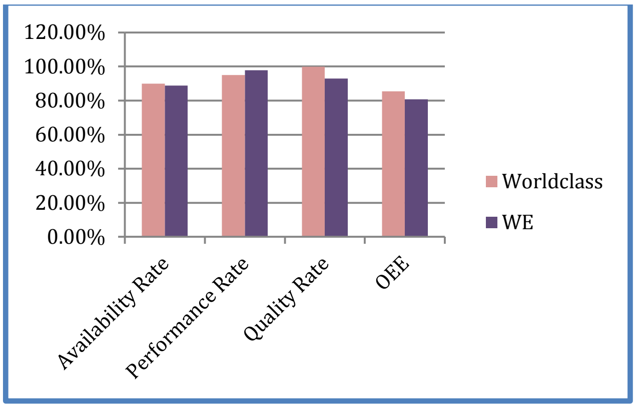

Fig 14 Before Implementation of TPM

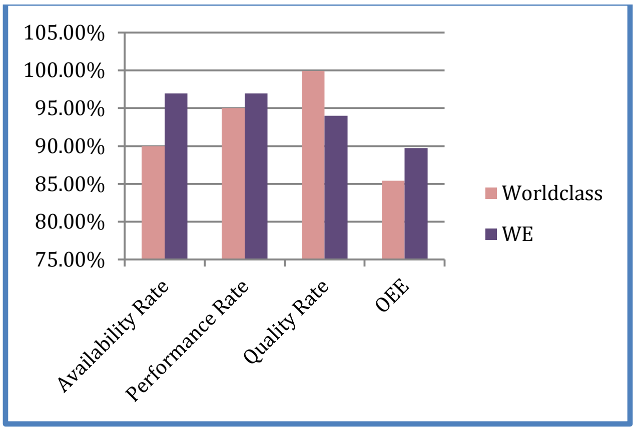

Fig 15 After Implementation Of TPM

Conclusion

Thesis is a practical application applying Total Productive Maintenance approach to HELICAL ASSEMBLY OF GEARBOX IN ELECON ENGG. CO. LTD. ANAND to reduce the material movement and cycle time of the product.

The studies aim initially scrutinizing the maintenance policy of the plant and apply the approach of TPM for improving the production effectiveness by identifying and eliminating production losses in the production system through active involvement participation of all employees. Investigation of plant machines workers are not involve for inspection and this is proactive maintenance policy of company.

The cycle time is reduced to total of **720 minutes** of total cycle time previously as shown in figure.

Also the material movement, scheduling and process are been improvised.

Table 17 Comparison after and before TPMCycle Time:

Assembly data		
	Total minutes before	Total minutes after
Assembly time	4297	2587
Authorized Lunch breaks	1920	1550
Total Available time	6217	4407

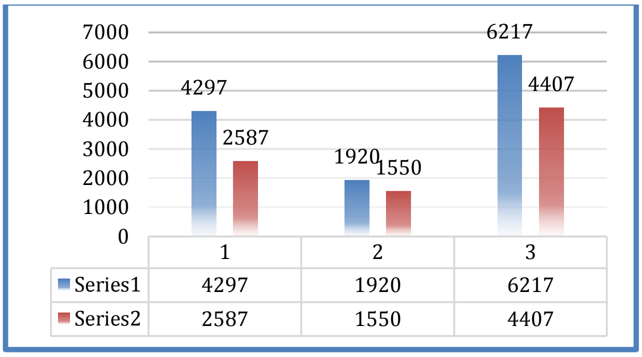

Fig 16 Cycle time comparison before and after TPM

References

NilmaniShahu ,Sridhar K. August 2013,Methodoly of evaluating overall equipment effectiveness in cylinder liner manufacturing firm through Total Productive Maintenance, International journal of industrial engineering and technology ,ISSN :2277-4769, volume 3,Issue 3 ,1-10.

Ahuja, I.P.S., Khamba, J.S. &Choudhary, R. (2006). Improved organizational behavior through strategic total productive maintenance implementation. Paper No. IMECE2006-15783, ASME International Mechanical Engineering Congress and Exposition (IMECE), Chicago, IL, November 5-10, 1-8.

I.P.S.Ahuja and J.S.Khambha,(2008),Total Productive Maintenance and literature directions International journal of quality and reliability,vol.25,No.7,2008,pp 709-756.

Bhadury, B. (2000). Management of productivity through TPM. Productivity, 41(2), 240-51.

Kalbande DR, Sawlekar S V,G T Thampi(2010)Total Productive Maintenance A case study in manufacturing industry, Industrial Engineering Journal, NITIE, VolII& issue 1

Thomas R. Promoski, (April 2004),Total Productive Maintenance concept and review principal consulting engineer, brooks automation Inc

Suzuki T 1992, TPM in Process Industry, Productivity Press, New York, U.S.A

Goyal Ravikumar, Maheshwari Kapil, (2013),Maintenance :From Total Productive to world class maintenance. International Journal of scientific research and reviews, 2(1), 1-23.

Ranjeet M. Jadhav, Morosin Alessandro, S. H. Sawant, (2012),Total Productive Maintenance aspect : A journey towards manufacturing excellence, International Journal of mechanical and civil engineering ,ISSN: 2278-1684,PP:-51-59.

F. Ireland and B.G.Dale, (2001), A study of Total Productive Maintenation implementation, Journal in quality in maintenance Engineering ,Vol.7,2001,pp 183-191.

Dal, B., Tugwell, P. and Great banks, R. (2000), Overall equipment effectiveness as a measure for operational improvement: a practical analysis, International Journal of Operations & Production Management, Vol. 20 No. 12, pp. 1488-502

Melesse Workneh Wakjiraand and Ajitpalsinh (February 2012),Total productive Maintenance :A case study in manufacturing industry, Global Journal of Research and Engineering in Industrial Engineering, vol.12,issue 1.

Jagtarsinh, Vikash Rastogi, and Richa Sharma,(December 2013), Total Productive Maintenance A review :Case study in automobile manufacturing industry, International journal of current Engineering and technology,ISSN:2277-4106.

Amit Kumar Gupta and Dr.R.K.Garg,(2012),OEE improvement by TPM: A case study, International journal of IT and Engineering and applied science Research, ISSN 2319-4443.

Venkatesh J 2007, An Introduction to Total Productive Maintenance, The Plant Maintenance Resource Center

Ki Young Jeong and Don T.philip,(2001),Operational efficiency and measurement effectiveness International journals of Operational and production Management ,vol.21,No.11,pp 144-3577.

A.Bangar, Hemlata Sahu, Jagmohan Batham, (2013),Improving Overall equipment effectiveness by implementing Total Productive Maintenance in Auto industry, International Journal of emerging technology and advanced engineering,Vol.3 ,Issue 6.

BhimasenSoragaon, Nagaraj L Hiregoudar, S B Mallur,(2012) Development of a Conceptual Model for the Measurement of Overall Worker Effectiveness (OWE) In Discrete Manufacturing SMES, International Journal of Engineering and Innovative Technology ISSN: 2277-3754 Volume 2, Issue 3, .

Hemant Singh Rajput, PrateshJayaswal,(2012), Total Productive Maintenance (TPM) Approach To Improve Overall Equipment Efficiency International Journal of Modern Engineering Research, Vol.2, Issue.6, Nov-Dec. 2012 pp-4383-4386 ISSN: 2249-6645.

Manu Dogra, Vsihal S. Sharma, Anish sachdeva J.S. Dureja,(2011) TPM- a key strategy for productivity improvement In process industry Journal of Engineering Science and Technology, Vol. 6, No. 1,PP 1 – 16

Vijay D.Kedaria, Prof.Vivek A. Deshpande, (2013),A Total Productive Maintenance Methodology: A Review, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 4, March 2014,ISSN 2250-2459.

Books

R.C.Mishra, K.Pathak Maintenance Engineering and Management Second edition, 2013, PHI Publication, Page no.287-297.

V.P.Sohani, Maintenance Management , Symbiosis center for distance learning pune, July 2004, Page no.311-358.

Websites

http://www.tpmclub.org
http://www.hul.co
http://www.jipm.org