Journal of Manufacturing Engineering, December 2009, Vol. 4, Issue 4, pp 274-282

APPLICATION OF MAINTENANCE PLANNING AND CONTROL FOR MANUFACTURING INDUSTRY: A CASE STUDY

***Rupinder Singh[1], N S Bhangu[2] and Sanjeev Kumar[3]**

[1]Department of Production Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab.India.-141006
[2]Department of Electrical Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab. India-141006
[3]Department of Mechanical Engineering, Haryana College of Technology & Management, Kaithal, India-136 027

ABSTRACT

Recent technologies are characterized by high level of automation deploying complex and sophisticated machines. The aim here is to achieve higher productivity and profit in an organization. The reduction in down time (maintenance time of the machines) is a step towards getting a maximum output from machines. In the present research work a systematic approach for maintenance planning and control has been applied on one of the critical unit, 'Machine building division' of mechanical manufacturing industry as a case study. Down time or maintenance time has been reduced by analyzing the failure pattern of critical parts of all types of machines. The study suggested that with proposed maintenance plan, down time of machine shop can be reduced by 9.77% and monitory benefit to company due to new maintenance policy is of Rs. 28, 04023/- for one time maintenance in total life span of equipment (based upon maintenance periodicity).

Keywords: *Maintenance, Planning, Manufacturing.*

1. Introduction

Maintenance means, "To keep fit any system for use." It may be defined as a combination of any actions carried out to retain an item in or restore it to, an acceptable condition. Maintenance is the procedure to keep the equipments, machines and other plant facilities in working conditions to ensure maximum plant availability. In maintenance common problem of equipments are ageing and deterioration. As the mechanical systems became more complex, there was more scope for failures and so down time started affecting the industry, hence efficiency and productivity of the plant is reduced.

Maintenance planning and scheduling consist of two main phase i.e. planning & scheduling. Planning of maintenance job basically deals with answering two questions "What" and "How" of the job that is, "What" jobs/ activities to be done and "How" those jobs/ activities are to be done [1]. While answering these two questions many other supplementing questions need to be answered i.e. "whether job to be done", or "why the job to be done" etc. Job scheduling of a maintenance job basically deals with answering two questions "who" And "when" of the job i.e." Who "would do the job and "When" the job is to be done or started?

Ulusoy et al. [2] designed a preventive maintenance (PM) planning and control system and implemented in a large foundry to increase the performance and effectiveness of production facility. Kenne and Boukas [3] presented the analysis of the optimal production and corrective maintenance planning problem for a failure prone manufacturing system consisting of several identical machines to minimize the cost of surplus down time and repair activities. Artana and Ishida [4] address a method for determining the optimum maintenance schedule for components in wear out phase. The interval between maintenance for the components is optimized by minimizing the total cost. Cassady and Kutanoglu [5] proposed an integrated model that simultaneously determines production scheduling and preventive maintenance planning decisions so that the total weighted tardiness of jobs were minimized. Cassady and Kutanoglu [6] proposed an integrated model that simultaneously determines production scheduling and preventive maintenance planning decisions so that the total weighted tardiness of jobs were minimized and concluded results in an average improvement of approximately 30%. Kumar [7] highlighted maintenance planning and scheduling for a cement plant. The results of study suggested that it was not always necessary that, particular maintenance strategy was useful for overall plant maintenance; rather it was systematic study which will economize maintenance actions of a process plant. In this study there was saving of 20 % of total maintenance time for

**Corresponding Author - E- mail: rupindersingh78@yahoo.com*

one time repair or replacement of each critical part of process plant. Dreyer [8] suggested advance maintenance planning and scheduling (AMPS) to reduce maintenance turnaround time and increasing system availability.

2. Need of Present Research Work

The literature review reveals that lots of work (theoretical and experimental) has been done on different aspects of maintenance. But very few researchers have reported on development of maintenance plans and schedules for general mechanical manufacturing industry. In the present research work an effort has been made to develop maintenance plan and schedule for mechanical manufacturing industry as a case study of ISGEC (Indian Sugar And General Engineering Corporation, Yamunanagar).

3. Objectives of Study

i. To reduce breakdown maintenance time by developing a schedule for maintenance planning and control.
ii. To compare the proposed maintenance scheduled with the existing maintenance schedule in terms of total time and money
iii. Down time or maintenance time reduction by analyzing the failure pattern of critical parts (of all types of machines namely Lathe Machine, Radial Drilling Machine, Planer, Milling Machine etc.).

4. Research Methodology and Data Collection

For the present research work consideration of the plant as a whole has been made and standard "SIX STEP METHOD" has been applied [9].

Step 1: Determination of critical plant units and production windows

The nature of plant was Batch/Job order production and after reviewing, last three year data it was observed that, Machine Building Division (MBD) was the most critical unit [10]. As because MBD has maximum downtime period of 7929 hours during 01-04-06 to 31-03-07, so this section was selected for case study.

Step 2: Classification of the plant into constituent Items

This step involves, complete classification of components in case of critical plant units and a partial classification in case of non-critical units. In Machine Building Division there were different types of machines namely Lathe Machine, Radial Drilling Machine, Planer, Milling Machine, Horizontal & Vertical Boring Machines, CNC Lathe and CNC Horizontal & vertical Boring Machines as shown in Fig. 1. In this step all the machines were classified in main parts and further all the main parts were critically classified in sub parts [11]. For example: Lathe Machine was classified in 5 main parts and further classified in 46 sub parts (Ref. Fig.2).

Step 3: Determination and Ranking the Effective Procedures

Determine the effective procedure for each item and best of these from cost and safety point of view should be selected [12]. Rank the expected offline work in order of increasing periodicity; for the same periodicity, parts should be rank in order of decreasing repair time. According to periodicity all the 51 parts were given rank from 01 to 51 and for example out of these some parts were rank in random order as shown in Table 1.

Step 4: Establish a Plan for the Identified Work

This method was depending upon whether the plant was series- continuous, product flow, batch product flow, and batch or vehicle fleet. Here the planning for maintenance work has been carried out for all parts which were shown in previous step. All the 51 parts which has been given rank in Step-3 were planned and arranged in order [13]. After this the total maintenance time for all types of machines were calculated from the table which were established in this step. For example: the total maintenance time for lathe machine was 904 hours with existing maintenance policy. Planning of Maintenance Work for Lathe Machine has been shown in Table 2. In the same manner the Planning of Maintenance Work for other remaining parts can be done.

Step 5: Establishment of a schedule for the on-line maintenance, off-line window maintenance the shutdown work

In the case of online maintenance the work can be scheduled independently down to the item level. Offline work can be carried out in production windows or as a part of the agreed shutdown and can usually be scheduled by agreement with production department However, it was important to take into consideration the approximate periodicity of the subsequent corrective workload when planning the resources. Parts, which were of same maintenance periodicity, and same components of machine, these should be replaced/ repaired simultaneously and therefore time can be saved.

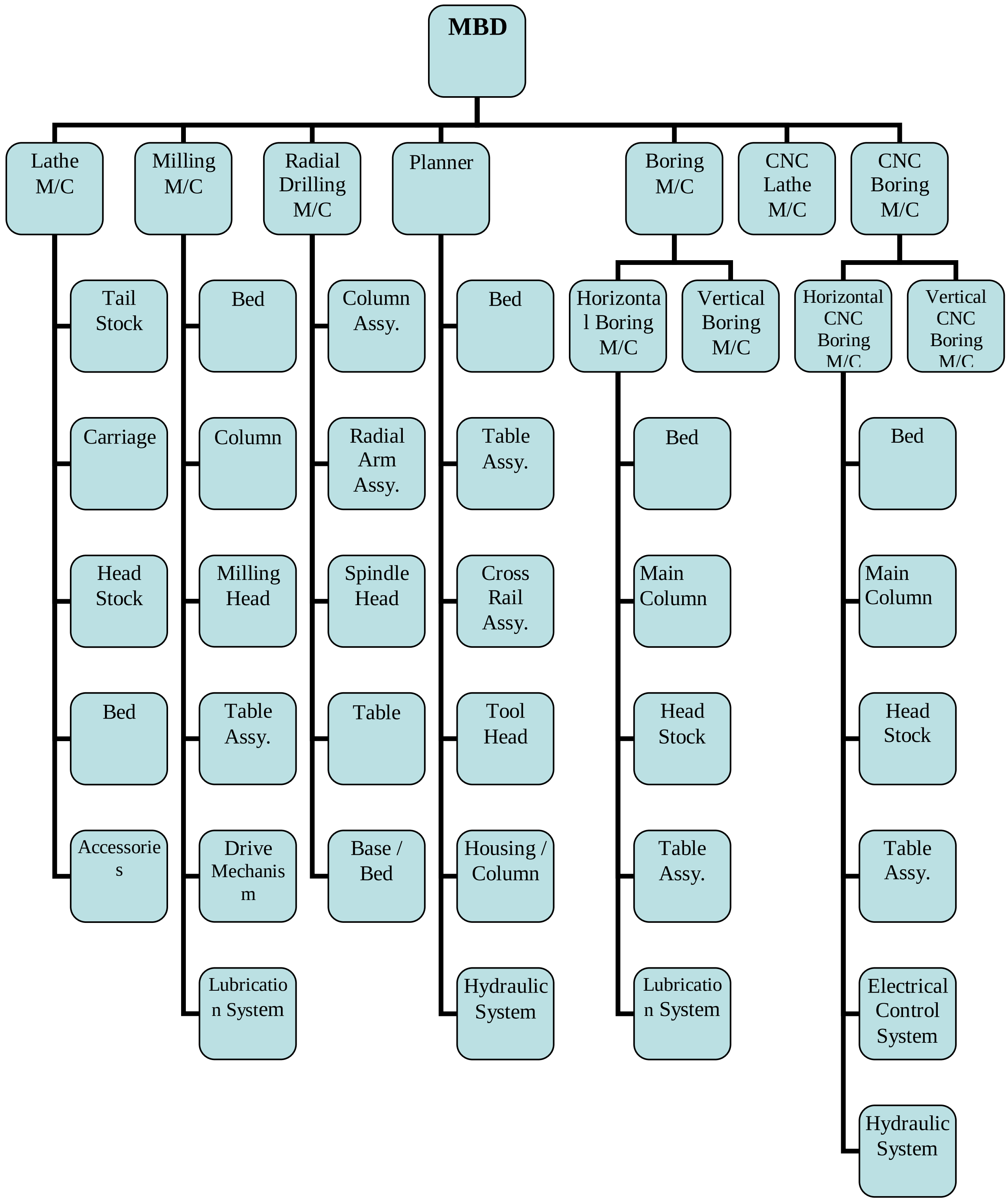

Fig. 1 Constituent Items of MBD

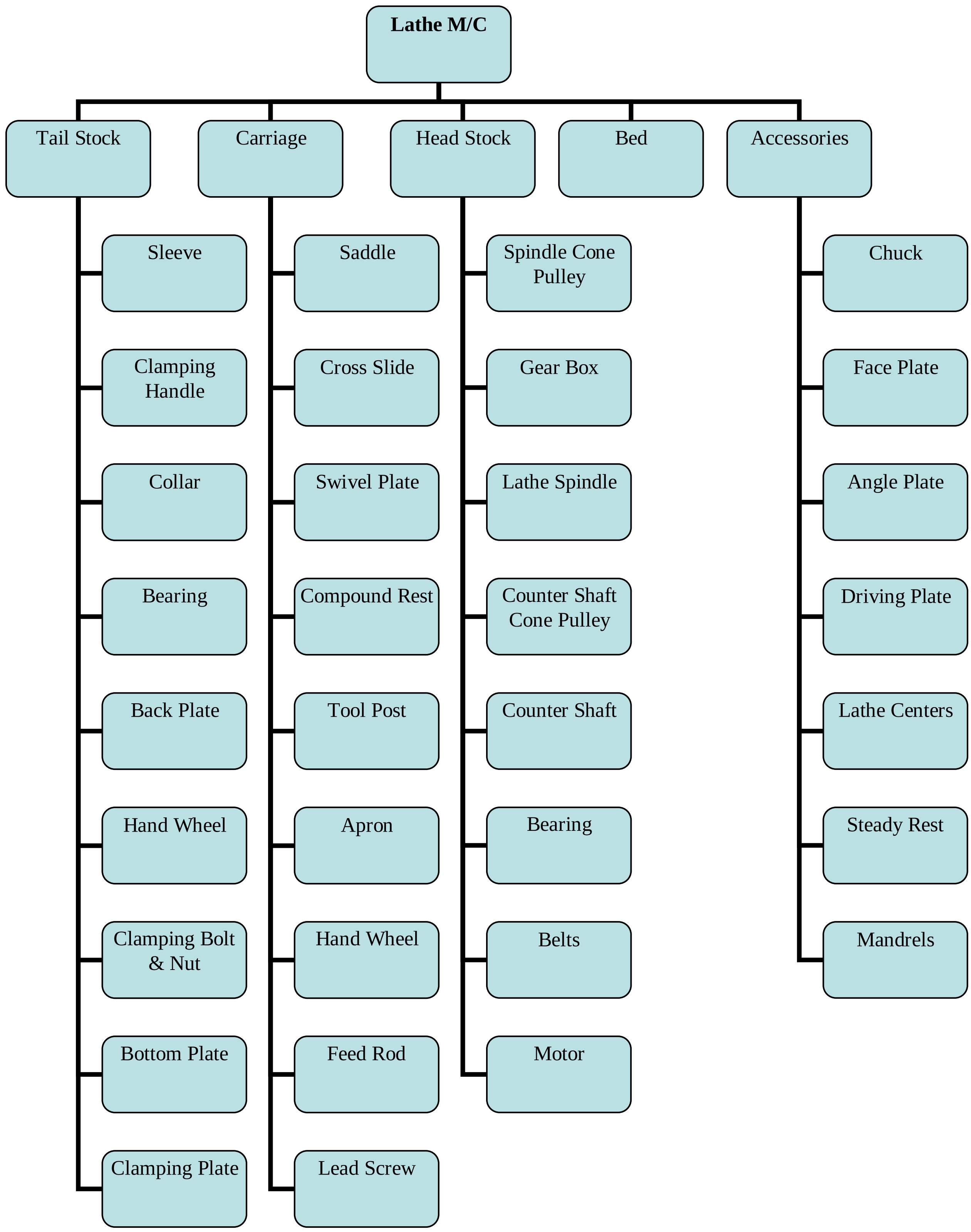

Fig. 2 Constituent Items of Lathe Machine

Table 1: Ranking the Parts of Lathe Machine

Part Name	Life (Year)	Timing	Online/ Offline	Periodicity	Time (Labour)	Initial Maintenance Plan	Online/ Offline	Periodicity (Years)	Time	Man Hours	Rank
Tail Stock											
Sleeve	15	V.C.M.	Offline	Half Yearly	30 Min. (2 Fitter)	Repair	Offline	5	6 Hours (2 Fitter)	12	28
Clamping Handle	25	V.C.M.	Offline	Quarterly	10 Min. (1 Fitter)	Replace	Offline	25	2 Hours (2 Fitter)	4	51
Collar	10	V.C.M.	Offline	Monthly	20 Min. (1 Fitter)	Replace	Offline	6	2 Hours (2 Fitter)	4	35
Back Plate	15	V.C.M.	Offline	Monthly	20 Min. (1 Fitter)	Repair	Offline	5	1 Hour (1 Fitter)	1	31
Back Plate Screws	10	V.C.M.	Offline	Quarterly	5 Min. (1 Fitter)	Replace	Online	5	30 Mins. (1 Fitter)	0.5	33
Hand Wheel	25	V.C.M.	Offline	Quarterly	10 Min. (1 Fitter)	Repair	Online	10	2 Hour (1 Fitter)	2	48
Bearing/Bush	15	V.C.M.	Offline	Monthly	30 Min. (2 Fitter)	Replace	Online	2	4 Hours (2 Fitter)	8	7

Table 2: Planning of Maintenance Work for Lathe Machine

Part Name	Life (Year)	Timing	Online/ Offline	Periodicity	Time (Labour)	Initial Maintenance Plan	Online/ Offline	Periodicity (Years)	Time	Man Hours	Rank
Counter Shaft Pulley	10	P.M.	Offline	Weekly	30 Min. (2 Fitter)	Repair	Offline	01	48 Hours (2 Fitter)	96	01
Spindle Cone Pulley	15	P.M.	Offline	Weekly	20 Min. (2 Fitter)	Repair	Offline	01	12 Hours (3 Fitter)	36	02
Main Motor	10	P.M.	Offline	Weekly	1 Hour (2 Fitter)	Repair	Offline	02	72 Hours (2 Fitter)	144	03
Clutch Mechanism	05	P.M.	Offline	Monthly	1.5 Hour (2 Fitter)	Repair	Offline	02	32 Hours (1 Fitter)	64	04
Cross Slide Feed Screw	10	P.M.	Offline	Monthly	15 Min. (2 Fitter)	Repair	Offline	02	8 Hours (2 Fitter)	16	05
Compound Rest Feed Screw	10	P.M.	Offline	Monthly	10 Min. (2 Fitter)	Repair	Offline	02	6 Hours (2 Fitter)	12	06

Table 3: Time Saved due to Combination of Activities for Lathe Machine

Combined Activities	**Previous Time**	**Proposed Time by Labour Adjustment**	**Total Time (Hrs)**	**Time Save due to Combination**
Tail Stoke Assembly				
a) Screwed Spindle b) Screwed Spindle Nut	16 Hrs (2 Fitter) 4 Hrs (2 Fitter)	20 Hrs (2 Fitter)	18	2 Hrs
a) Sleeve or Barrel b) Back Plate c) Screws 2 Nos.	6Hrs (2Fitter) 1Hrs (1Fitter) 30Min (1Fitter)	6 Hrs 45 Min. (2 Fitter)	6	45 Min
a) Clamping Bolt b) Clamping Nut c) Clamping Plate	4 Hrs (2Fitter) 1 Hrs (1 Fitter) 10 Hrs (2 Fitter)	14 Hrs 30 Min. (2 Fitter)	13	1 ½ Hrs
Carriage				
a) Cross Slide Feed Screw b) Cross Slide Feed Screw Nut c) Compound Rest Feed Screw d) Compound Rest Feed Screw Nut	8 Hrs (2 Fitter) 4 Hrs (2 Fitter) 6Hrs (2 Fitter) 2 Hrs (2 Fitter)	20 Hrs (2 Fitter)	18	2 Hrs
a) Split Half Nut b) Feed Rod c) Lead Screw	4 Hrs (2Fitter) 10Hrs (2Fitter) 24Hrs (2 Fitter)	38 Hrs (2 Fitter)	36	2 Hrs
a) Cross Slide b) Saddle c) Swivel Plate d) Compound Rest	64Hrs (2 Fitter) 16Hrs (2 Fitter) 16Hrs (2Fitter) 24Hrs (2 Fitter)	120 Hrs (2 Fitter)	110	10 Hrs
a) Apron Housing b) Gears c) Levers	10Hrs (2Fitter) 30Hrs (4Fitter) 16Hrs (2Fitter)	43 Hrs (2 Fitter)	40	3 Hrs
a) Cross Feed Hand Wheel b) Longitudinal Feed Hand Wheel	6Hrs (2 Fitter) 2Hrs (1 Fitter)	7 Hrs (2 Fitter)	6	1 Hrs
Head Stoke				
a) Spindle Cone Pulley b) Counter Shaft Pulley	12Hrs (3 Fitter) 48Hrs (2 Fitter)	44 Hrs (3 Fitter)	40	4 Hrs
a) Main Motor b) Belt	72Hrs (4 Fitter) 4Hrs (2 Fitter)	74 Hrs (4 Fitter)	72	2 Hrs
a) Gear b) Lathe Spindle c) Tapered Bush	30Hrs (4Fitter) 72Hrs (3 Fitter) 8Hrs (2Fitter)	88 Hrs (4 Fitter)	83	5 Hrs
Accessories				
a) Face Plate b) Angle Plate c) Driving Plate d) Chuck	8Hrs (2Fitter) 4Hrs (2Fitter) 8Hrs (2Fitter) 8Hrs (2Fitter)	28 Hrs (2 Fitter)	26	2 Hrs
a) Lathe Centre b) Steady Rest	24 Hrs (2 Fitter) 12Hrs (2Fitter)	36 Hrs (2 Fitter)	34	2 Hrs
Total Hours	**594.5**	**539.25**	**502**	**37.25**

Table 4: Proposed Maintenance Plan for Lathe Machine

Sl. No.	Maintenance Action	Time (Labour)
1	Clamping Handle should be replaced	2 Hrs (2 Fitter)
2	Collar should be replaced	2 Hrs (2 Fitter)
3	Hand wheel should be repaired	2 Hrs (1 Fitter)
4	Bearing/Bush should be replaced	4 Hrs (2 Fitter)
5	Screw spindle and screw spindle nut should be repaired/replace simultaneously.	18 Hrs (2 Fitter)
6	Sleeve back plate and screws should be repaired / replaced simultaneously.	6 Hrs (2 Fitter)
7	Clamping bolt, nut and clamping plate should be replaced/repaired simultaneously.	13 Hrs (2 Fitter)
8	Bed guide way should be repaired.	24 Hrs (4 Fitter)
9	Cross slide feed screw, nut, compound feed screw and nut should be repaired / replaced simultaneously.	18 Hrs (2 Fitter)
10	Saddle, cross slide, swivel plate and compound rest should be repaired simultaneously.	110 Hrs (2 Fitter)
11	Split half nut, feed rod and lead screw should be repaired and replaced simultaneously.	36 Hrs (2 Fitter)
12	Tool post should be repaired.	4 Hrs (1 Fitter)
13	Clutch should be repaired.	32 Hrs (2 Fitter)
14	Apron housing, gears and levers should be repaired simultaneously.	40Hrs (4 Fitter)
15	Cross feed hand wheel and longitudinal both should be replaced simultaneously.	6 Hrs (2 Fitter)
16	Cone pulley and counter shaft pulley should be repaired simultaneously.	40 Hrs (3 Fitter)
17	Main motor and belts should be repaired / replaced simultaneously.	72 Hrs (4 Fitter)
18	Gears, lathe spindle and tapered should be repaired/replaced simultaneously.	83 Hrs (4 Fitter)
19	Bearing should be replaced.	48 Hrs (4 Fitter)
20	Counter shaft should be repaired.	16 Hrs (2 Fitter)
21	Feed reverse lever should be replaced.	16Hrs (2 Fitter)
22	Live centre should be repaired.	40 Hrs (2 Fitter)
23	Gear head stoke should be repaired.	48 Hrs (2 Fitter)
24	Face plate, angle plate, driving plate and chuck should be repaired simultaneously.	26 Hrs (2 Fitter)
25	Lathe centre and steady rest should be repaired simultaneously.	34 Hrs (Fitter)
26	Mandrels should be repaired.	40 Hrs (3 Fitter)
	Total Hours	**780 Hrs**

For example: after the combination of activities, parts were replaced / repaired simultaneously, and then it was observed that total maintenance time for lathe machine was 780 hours. Hence the total maintenance time can be saved / reduced of 124 hours i.e. 13.72% in case of lathe machine. In the same way the total maintenance time can be saved / reduced for other machines namely Radial Drilling Machine, Planer, Milling Machine, Horizontal & Vertical Boring Machines, CNC Lathe and CNC Horizontal & vertical Boring Machines. For example: in Table 3 it was shown that how the various activities can be combined and how the maintenance time or down time can be saved / reduced.Table 4 shows the proposed maintenance plan for Lathe Machine. This table elaborates the maintenance time and labour requirement for repaired/replaced items (by individual or combined maintenance activities) of lathe machine [14]. In the same manner it has been calculated for other machines. From Table 4 it can be concluded that total maintenance time for lathe machine was 780 hours with new proposed maintenance plan.

Step 6: Establishment of corrective maintenance guidelines

In spite of preventive maintenance there will still be some unexpected failure, for example those due to items, which fail randomly and without monitor able warning. Such failures have to be planned for in terms of spares and manpower. In the case of critical units, careful consideration must also be given to repair methods, documentation and decision guidelines [15]. Here some general and corrective maintenance guidelines for different types of machines were established.

5. Results and Discussions

In Machine Building Division there were 07 No. of Lathe Machines, 04 No. of Radial Drilling Machines, 02 No. of Planer Machines , 03 No. of Milling Machines , 11 No. of Boring Machines, 05 No. of CNC Lathe Machines and 04 No. of CNC Boring Machines i.e. total 36 machines of different types.

For Lathe Machine total maintenance time of one machine was 904.5 hours with the existing maintenance method, hence for 07 machines the total maintenance time were 6331.5 hours. By applying the proposed “SIX STEPS METHOD” the maintenance time of one machine was 780 hours, and for 07 Lathe Machines the total maintenance time were 5460 hours. Hence there were reduction of 871.5 hours in maintenance i.e. 13.76% reduction of maintenance hours. In the same way there were reduction of 324 hours in maintenance i.e. 14.2% reduction of maintenance hours for radial drilling machine, for Planer machine there were reduction of 254 hours in maintenance i.e. 9.56% reduction of maintenance hours, for Vertical milling machine there were reduction of 120 hours in maintenance i.e. 8.65% reduction of maintenance hours, for Boring machine there were reduction of 770 hours in maintenance i.e. 5.6% reduction of maintenance hours, for CNC Lathe Machine there were reduction of 357.5 hours in maintenance i.e. 15.5% reduction of maintenance hours, for CNC Boring machine there were reduction of 687 hours in maintenance i.e. 11.6% reduction of maintenance hours.

All machines in Machine Building Division were classified into six main group likes Extra Heavy Machine, General Machine, Heavy Machine, Light Machine, Medium Machine and Super Heavy Machines. Table 5 shows comparison between existing and proposed maintenance plan.

Table 5: Comparison between Existing Maintenance Plan and Proposed Maintenance Plan

S. No	Machine	No. of M/c	Total time for Existing Maint. Plan (hrs.)	Total time after SIX STEP METHOD (Hours)	Reduction of Hours	% age Reduction of Maint. Hrs.
1.	Lathe	07	6332	5460	871.5	13.76
2.	Planer	02	2656	2402	254	9.56
3.	Radial Drilling	04	2282	1958	324	14.2
4.	Milling	03	1386	1266	120	8.65
5.	Horizontal Boring	11	13750	12980	770	5.6
6.	CNC Lathe	05	2299	1941.25	357.5	15.5
7.	CNC Boring	04	5927	5240	687	11.6
	Total	**36**	**34631.2**	**31247.25**	**3384**	**Avg.= 9.77**

Total maintenance times of all the machines with the existing method were 34631.25 hours. By using the proposed “SIX STEP METHOD” the total maintenance time were 31247.25 hours, so there was reduction of 3384 hours i.e..9.77 % and monitory benefit

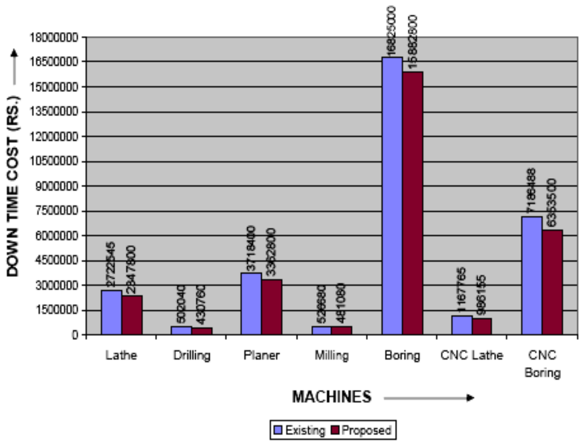

Fig. 3 Comparison of Monitory Benefits (Down Time Cost) due to Existing and New Proposed Maintenance Policy

to company due to new maintenance policy is of Rs. 28,04023/- for one time maintenance in total life span of equipment (based upon maintenance periodicity). Fig. 3 shows the Comparison of monitory benefits (down time cost) due to existing and new proposed maintenance policy.

From the above study it has been found that down time or maintenance time in MBD can be reduced by analyzing the failure rate of each critical part of different machines by using six step methods. By applying the proposed method, maintenance periodicity of each and every part can be predicted and a new maintenance plan can be scheduled. With the proposed maintenance plan there will be a reduction in maintenance time (down time) which will save useful productive time. A small reduction in maintenance time will increase its production and there will be monitory benefit to the company due to new proposed maintenance policy.

6. Conclusions

The study suggests that like process industry, 'six-step method' can be successfully applied on batch production units also. In mechanical manufacturing units it is always desirable to reduce breakdown maintenance time or down time. So, it is important to keep the machines in operation as the failure of each critical part can stop whole operation. Following conclusions can be drawn from the study.

i. It has been found that by using six step methods there will be direct saving of 9.77% of the total maintenance time for one time repair or replacement of critical parts in Machine Building Division.

ii. By using proposed model of maintenance, organization can save lot of time and money in maintenance work which is Rs. 28,04023/- for one time maintenance in total life span of equipment (based upon maintenance periodicity) due to proposed maintenance policy

References

1. *Kumar Harmesh, Bhangu N S, Singh Rupinder and Pahuja G.L., (2009), "Implementation of Reliability Centered Maintenance in Lamp Manufacturing Unit", Journal of Manufacturing Engineering, Vol. 4(3), 210-217*

2. *Giindiiz Ulusoy, Ilhan and Nezih Soydan, (1992), "Design and Implementation of A Maintenance Planning and Control System", International Journal of Production Economics, Vol. 24, 263-272.*

3. *J P Kenne and E K Boukas (1997), "Production and Corrective Maintenance Planning Problem of a Failure Prone Manufacturing System", Proceedings of the American Control Conference, Albuquerque, New Mexico, 1013-1014.*

4. *Artana, K B and Ishida K (2002), "Spreadsheet Modeling of Optimal Maintenance Schedule for Components in wear-out phase", Reliability Engineering and System Safety, Vol. 77 (1), 81-91.*

5. *Cassady C Richard and Kutanoglu Erhan (2003), "Minimizing Job Tardiness using Integrated Preventive Maintenance Planning and Production Scheduling", IIE Transactions on Reliability, Vol. 35,503–513.*

6. *Cassady C Richard and Kutanoglu Erhan (2005), "Integrating Preventive Maintenance Planning and Production Scheduling for a Single Machine", IEEE Transactions on Reliability, Vol. 54, (2), 304-309.*

7. *Kumar Harish, (2006) "Maintenance Planning and Schedule for a Cement Plant: A Case Study", M.Tech Thesis, P.T.U. Jalandhar, 19 - 60.*

8. *Dreyer Samuel L (2006), "Advance Maintenance Planning and Schedule", IEEE, 341-347.*

9. *Kelly Anthany (1991), "Maintenance Planning and Control", Affiliated East-West Press Pvt. Ltd., New Delhi, 52-64.*

10. *Garg H P (2002), "Industrial Maintenance", S. Chand & Company Ltd., New Delhi, 23-66.*

11. *Huang Jia-Yen (2006), "New Search Algorithm for Solving the Maintenance Scheduling Problem for a Family of Machines", Optimization Methods and Software, Vol. 21 (3), 461–477.*

12. *Jain R K (2004), "Production Technology", Khanna Publishers, New Delhi, 790-806.*

13. *Jeong I-J, Leon V J and Villalobos J R (2007), "Integrated Decision-Support System for Diagnosis, Maintenance Planning, and Scheduling of Manufacturing Systems", International Journal of Production Research, 45,(2), 267–285.*

14. *Mishra P C and Pathak & K, (2003), "Maintenance Engg. & Management", PHI, New Delhi, 68-81.*