UNIT I

L_1 PRINCIPLES & PRCTICES OF MAINTENANCE PLANNING

Maintenance:

It is the routine and recurring process of keeping a particular machine or asset in its normal condition o that it can deliver the excepted performance or service without any loss or damage.

Principles of Maintenance Planning

Maintenance principles are followed in a system to guide the staff to work efficiently and effectively to achieve the overall objectives of the maintenance system.

i) Plant Management in Maintenance work:

The main role of the maintenance function is to provide safe and effective operation of the equipment to achieve the designed targets on time with economic usage of resources.

ii) Production and Maintenance Objectives:

The plant is driven by the production targets. The objective of these maintenance function is to support these targets.

Information based Decision Making:

The maintenance objectives are successfully achieved by the use of reliable information system.

Planning of Maintenance Function :

All the maintenance functions are to be carefully executed by a way of proper planning to ensure the effective utilization of manpower and materials.

Manpower for Maintenance:

The manpower requirements of the maintenance system must be carefully evaluated based on the time and motion study.

Workforce control:

Determination of exact workforce required to meet the maintenance objectives of the system is difficult task due to the element of uncertainty. Hence the proper control and monitoring of workforce are needs to be ensured .

Role of spar parts:

A good maintenance management system requires appropriate tools. So the system should have good quality tools and that too available in required quantities to ensure the proper function of the maintenance works.

Important Factor to be considered in Maintenance Planning

The maintenance work include the following factors

- Job Distribution
- Programme
- Man Power Allocation
- Staffing
- Planning Techniques
- Planning Procedure.
- Maintenance Control

Jot Distribution :

The first and foremost task in maintenance planning is the distribution of the pots to the personnel for preventive and emergence maintenance works.

Programme:

A maintenance programme is a well formulated combination of the available skills and resources that ensures optimum and appropriate utilization to meet the objective of the organization.

Man Power Allocation:

It is the most important task of the maintenance management group. The central idea of man power allocation can be drafted using the information available from maintenance records and planning the tasks to meet the objectives of the organization.

Staffing:

It is the task of provided the required manpower for the maintenance

function. The advantage of preventine maintenance is that the work can be planned and scheduled properly for the effective use of resources.

Planning Techniques:

The planning methods are Gantt charts, Critical path method are recently used for maintenance planning and scheduling.

Maintenance Control:

It is the auditing technique to ensure the effective utilization of the maintenance budget. This involves the integration of with the system.

2 marks

L2

Important and benefits of sound maintenance management system

The profit of any industry depends only on the return of the investment. The capital cost and operating cost are the major factors involved in any industrial investment. The life of the equipment and maintenance schedule information provided by manufacturer may not be realized in practice to make the need for having a sound management system.

The following are the benefits of sound maintenance management system.

- Minimization of colourtime.
- Improvement in availability of system.
- Extended life of equipment.
- Safety and smooth operation of the process
- Provide adequate back up supply
- Minimization of normal expected wear and tear of equipment.
- Safety of the personal involved in the organization.
- Increased reliability of the system.
- Provide proper working environment.

RELIABILITY IN MAINTENANCE

The concept of reliability has found increased use in industries engineering maintenance and management.

Need for reliability of Maintenance :

The reliability of a system, equipment and product is very important aspect of quality for its consistent performance over the expected life span.

Reality is defined as the probability that ac component / system, when operating under given condition will perform it intended functions adequate for a specified period of time. It refers to the like hood that equipment will not fail during its operation. The four important factors required in the determination of reliability are

- Reliability expressed as probability
- Adequate performance acquirements
- Duration of adequate performance.
- Environmental or operating conditions.

i) Realiability expressed as probability

it is the ratio of the number of times we can expect an event to occur to the total number of trail undertaken. A Reliability factor can be expressed as probability. A reliability factor equal to one means that device performs satisfactorily for the prescribed duration under the give environmental condition.

ii) Adequate Performance Requiement:

a system may perform satisfactorily even though one or more components

may not be functioning. In reliability analysis there is a need to define the magnitude of satisfactory or adequate performance of the system.

iii) Duration of Adequate Performance:

The duration of adequate performance is used to state the time up to which the desired performance of the system is achieved under the given operating conditions.

iv) Environmental or Operating condition:

environmental condition indicate the prevailing conditions at which the system is under operation.

Failure pattern of equipment

The failure pattern of equipment over its whole life cycle can be represented in the diagram given below. In phase I, the failure pattern inherent in a new product because of manufacturing or design defects. Phase II shows the useful life period of an equipment when the failure rates are normally modulate at the equipment gets set to the working environment. In Phase III, the failures are excusing due to wear out failure that are caned due to again of the equipment.

L3 – Reliability (R)

Reliability is the probability of a device performing its purpose adequately for the period intended under the give operating conditions.

Reliability Model:

A basic measurement of the reliability of the product ie its probability of is that of mean time between failures. Suppose that products are taken at random from a large group and let of them fail during the time period then the probability of failure during the period "t" is given by $P_t = \frac{n_t}{N}$

It is necessary to evaluate the performance of the product over the intended length of time T for the determination of reliability. Then

When a large number of products are tested so that the relative frequency becomes a smooth function f(t) of time. Then reliability expressed by

$$R_t = 1 - {}^{t} f(t)\, dt$$

Failure rate is approximately constant in that of the practical cases. Then function assumes the form of the exponential probability function as given by

$$F(t) = 1/Q\, e^{-t/q}\, dt.$$

$$R_t = e^{dt}$$

Probability of Failure

The probability of failure is the ratio of the number of unite that failed at specified period of time to the total population.

Mean Failure Rate (h)

The mean failure is the rate h is obtained by finding the mean of the failure rates for specified period of time.

Mean time is failure (MTTF)

Let t, is the time to failure for the first specimen, t is the time to failure for the second specimen and tn is the time to failure for the N specimen. Hence the mean time to failure for N specimens are

$$HTTF = (t1+t2+\ldots\ldots tn)\ /n$$

$$= 1/N$$

It is difficult to record the failure for each component when the numbers of specimens tested are large. Instead, we can record the number which fails during the specific intervals of time.

Mean time between failures (HTBF)

Mean time between failures (HTBF) is the mean or average time between successive failures of a product. Mean time between failures refers to the average time of breakdown until the device is beyond repair.

Mean time to Repair (MTTR)

Mean time to repair (MTTR) is the arithmetic mean of the time required to perform maintenance action. MTTR is defined as the ratio of total maintenance time and number of maintenance action.

MTTR = Total maintenance time

Number of maintenance action

Maintenance Action Rate:

Maintenance action rate is the number of maintenance action that can be cassied out on equipment per hour.

= 1/MTTR

Types of Reliability:

Reliability can be generally of two types

Inherent Reliability

It is associated with the quality of the material and design of machine parts

Achievable Reliability

It depends upon other factor such as maintenance and operation of the equipment.

L4- MAINTAINABILITY

It is a concept closely related to the characteristics of equipments design and installation. It is defined as the probability that a unit or system will be restored to specified working conditions within a given period when maintenance action is taken in accordance with the prescribed procedures and resources.

Availability

It is the ratio of the time at which the equipment is available for the designated operation service to the total time of operation and maintenance of

the equipment. It is also defined as the ration of equipments uptime to the equipment uptime and down time over a specified period of time.

The three types of availability are

- Inherent availability
- Achieved availability
- Operational availability

Inherent availability

It is the probability that a system or equipment shall operate satisfactorily when used under prescribed conditions in a ideal support environment without any scheduled or preventive maintenance at any given time.

Inherent availability = MTBM/ MTBM+MTTR

Achieved availability

It is the probability that a system or equipment shall operate satisfacily when used under prescribed conditions in an ideal support environment with periodic preventive and corrective maintenance at any given time.

Achieved availability = MTBM/ MTBM+M

Operational Availability

In industrial system a certain amount of delay will always caused by time element such as supply downtime and administrative downtime.

Operational availability = MTBM/ MTBM+MDT

Where MOT is the mean downtime is the satisfied mena of the downtimes including the supply downtime and administrative downtime.

Resources

Resources include men, sparks and tools involved in the task of maintenance.

Administration

It include a nearby of authority and responsibility for decision making and plans for the execution of work.

Workplanning and control system

This is the mechanism for planning and scheduling the wok. This also include the feedback of information to drive the maintenance effort to its defined objective.

The basic objective of the maintenance organization is the ensure that the maintenance function ae carried out effectively and hence to minimize the production loss due to maintenance. There has to be a close relationship between the production and maintenance departments to achieve the desired targets of the industry. Continuous monitoring of planned preventive maintenance schedules identififed for the identified for the equipment is required to complete the maintenance tasks in time.

A maintenance organization can be countered as made up of three basic and necessary components.

Resources

Administration

Work planning and control system.

Maintenance of modern equipment and industry requires a healthy, balanced and rationalized organization, devoted to achieve the goals of maintenance task. The organization required for any system can be formed after study of the existing continuous and also the future demands of the industry.

The increasing complexity of present day equipment maintenance management has brought into focus two other aspects known as maintainability and availability, both of them are closely related to reliability.

2 marks

L 5 – TASKS OF MAINTENANCE ORGANISATION

The tasks of the maintenance are as follows:

- Identification of organization roles pertaining maintenance function.
- Determination of maintenance workload.
- Uniform distribution of total maintenance work to all the personal in the department.
- Identification and assignment of essential works to the various sections of the maintenance department
- Proper knowledge about the technical experlise/ experience of the workers deputed for the particular part
- Proper training of the staff of maintenance to meet the growing demands of the industry and to catch up with the modern trends in maintenance.
- Designing the polices and procedures at an early stage to help the maintenance departe4mnet to achieve the goals of the industry.

Maintenance Functions and Activities

The functions and activities of the maintenance organization are as follows:

- Identifying areas for implementation of preventive maintenance program.
- Making suitable arrangements for maintenance facilities for carrying out the maintenance works properly.
- Planning an scheduling the total maintenance work

- Ensuring proper and timely supply of spare parts.
- Managing proper inventory control of materials spares and tools required for maintenance.
- Standardization of maintenance work.
- Implementing modifications to the existing equipment wherever possible.
- Assisting the purchase department in processing materials.
- Identification of obsdate and surplus equipment for replacement and disposals.
- Training of maintenance personnel.
- Analysis of future demands and forecast the role of maintenance activities.
- Implementation of safety norms and procedures
- Ensuring safety of personnel and equipment.

Types of maintenance organization

The selections of a type of maintenance system will largely depend on the structure of an industry. Maintenance organization can be broadly classified into three types as follows.

i) Decentralized

this is suitable for large sized plants where enter unit communication is difficult to get. In this type of organization the maintenance is difficult to get. In this type of organization, the maintenance is under the control of chief engineer of production to ensure understanding between the production and maintenance department.

ii) Controlized

this is suitable for small units where unit communication is feasible. In this typeof organization the maintenance is under the control of chief maintenance engineer. The responsibilities accountability is with the concerned department heads.

iii) Partially Controlized

this is the modified version of controlized maintenance organization and suitable for the industry where the units are located at far away locations.

In this type of organization, the maintenance personal attached with production unit will carryout the routine maintenance works. Scheduled maintenance works such as overhauls. Planned maintenance work, procurement of spare parts are under the control of chief maintenance engineer at the control office.

There are basically tow atleast two types of organization are followed in most of the industries. They are

- Line organization
- Line staff organization.

L6 – Line Organization

Line organization consists of a general foreman and a number of specialist foremen with their under them is shown below.

General Foreman

Foreman Electrical Storekeeper

The specialist foreman execute maintenance work in their respective areas while the general foreman supervises the total work under his control and the various maintenance tasks carried out in the industry. This kind of structure is an old type maintenance organization.

LINE STAFF ORGNISATION

A few more staff members such as storekeeper and clerk are added to the line organization to form the line organization structure as given below.

The advantage lies in separating the maintenance work from the storekeeping and the role of clerk is to record the maintenance activities. The recording of maintenance related activities helps the organization to restructure the strategies adopted to achieve the objectives of maintenance.

LINE STAFF ORGANISATION

Maintenance functional organization

Maintenance functional organization is the structure based on craft concept. In this organization structure persons joined the organization as appentices and devoted to higher positions such as forman after sufficient experience in their respective jobs. This organization the maintenance functional organization in which few workers are placed under each functional foreman.

Controlly Controlled Maintenance Organization

The limitation of this kind of maintenance is that it is possible onl for equipments which can be shifted to workshop.

Area Maintenance organization

Area maintenance organization provides better utility of manpower when the units are located at various locations.

For example mining industry, area maintenance manage takes care of maintenance for a particular area and is equipped with number of workers to carryout maintenance works including emergency work.

L7 – GENERAL ORGANIGATION OF MAINTANANCE DAPARTMENT

Externalmaintanance service

It is available in two forms contract maintenance service and manufacturers after sale service

Advantages of external maintenance service

- It is very economical
- Technically better and specialist are responsible for maintenance activities
- Skill preservation
- Better service
- Updating to modern and existing trends and needs

Outsourcing in maintenance

The term outsourcing assumed recent importance in the area of computer information technology and communication due to emergence of business process outsourcing (BPO) outsourcing is followed in small industries to hand once the maintenance activities to external agencies. This is due to the reason that economy of the industry does not permit to have maintenance people on their own. It is followed in large industries also ensure maximum control over the maintenance activities.

- Lost of maintenance is minimized
- No need for having maintenance as a department.
- Better quality of service achieved through employing specialists.
- Better maintenance practice
- Performance metrics are clearly defined and achieved by ooutsourcing the maintenance jobs

Maintenance Economics

Lift cost Analysis:

The factors to be considered in the purchase of equipment for industries include the cost, quality, performance and maintenance requirements. Some balance is to be made between the capital cost andn operating cost of the equipment in finding the suitability of the equipment.

Life cycle costing is the cost analysis for the equipment in an industry that accounts total cost of the equipment over a span of time which includes the capital cost, operating cost and maintenance cost. The aim of life cycle losting is to acertain the total cost of equipment over the span of its entire life period.

Advantages of life cycle costing

Integration of engineering, economics and financial aspects lead to the way of rotust metric for the selection and purchase equipment required for the industry.

Reduced operating and maintenance cost of equipments due to cost analysis over span of time.

It leads to the selection of proper and economically viable equipment.

Estimation of Economic Life of Equipment

The economic life of equipment depends on the maintenance of repair costs, availability an doperational efficenty. A plot of cumulative efficienty and maintenance and repair cost per cumulative hours vs operating hours of the equipment to find the economic lifie of the equipment.

Maintenance Cost

Budgets are allocated for all the activities in planning stage itself which includes the maintenance cost. The cost of maintenance is difficult to measure due to random nature of failures. The words on maintenance history may be useful in determining the cost.

L8 – Component of Maintenance Cost

The maintenance cost is comprised of two factore

- Fixed cost
- Variable cost

Fixed Cost

This includes the cost of support facilities including the maintenance staff.

Variable Cost

This include the consumption of spare parts, replacement of components and cost other facilities required to meet the requirements of maintenance.

The evaluation of maintenance cost should consider the following factors

- The evaluation of maintenance cost should consider the following factors.
- Cost of maintenance from the recorded data.
- Level and requirements of maintenance.
- Cost of replacement of components and assemblies subjected to wear and tear.
- Accounting the number of break downs with their levels
- Downtime of the equipment for want of maintenance repair.
- Penalty cost due to loss of production .
- Cost of manpower involved.
- Cost of additional manpower requirement for emergency breakdown and maintenance.

Maintenance Budget

The maintenance budget is sued to set aside crtain amount of money to meet the expenditures incurred in achieveing the objectives of maintenance. The following are the types of maintenance budget.

i) appropriation Budget

budget used to allocate money for each activity independently

ii) Fixed Budget

Fixed used to allocate money for a specified period of time.

iii) variable budget

dynamic allocation of expenditure based on maintenance requirements and activities.

Cost Minimization in Maintenance organization

- Controlized, planning, scheduling and control.
- Grouping of specialized workforce.
- Effective later utilization strategies.
- Proper and effective use of contract maintenance system to reduce the overhead costs on equipment and manpower.
- Purchase of reliable equipment and spares.
- Use of skilled and trained workforce.
- Proper selection of suitable type of spares, materials and bebricants.
- Proper safety education and formulating the safe practice.
- Constant appraisal and education to workforce about the objectives, stragies and modern techniques adopted in the area of maintenance.

Calculate the failure rate of a component from the following data

Number of components tested = 750

Period of time = 1000 hrs

No of failure reported for the given period of time = 5

Solution

Let R be the probability of reliable function for specified period of time and F be the probability of failure R + F = 1

Failure rate = No of failures in a unit time

= number of failures / time period.

= 5/750 x 1/1000

This is based on the assumption of uniform failure rate ofr the given period of time.

Probability of failure = 1-R = 1-99.34 = 0.66%

L9 – Problems

Problem – 1

Equipment is subjected to maintenance. Time constant for completing the work is 60 minutes. If MTTR is 0.3 hrs calculate the probability that it will met the desired specification.

Solution

Probability of maintenance equipment, M = 1 – e

Problem -2

A process plant consists of fire equipments connected in services as shown in figure given below. In this continuous production environment, the major failure is in the failure of the pumps delivering the fluid form one quipment to other.

Health -> Reader -> Cooler -> vessel -> Tank

P1 P2 p3 p4

Process plant with equipments connected in services.

The failure rate of pump delivered to the heater is 0.00001 per hr and the failure raters for the pump delivering the fluid to the reactor, cooler, sedimentation vessel and storage tank are 0.0002, 0.00018, 0.00003 and 0.00005 per hour. Calculate the reliability of the process plant.

Solution

Problem 3

In the life testing of ten specimens in an industry, the time to failure for each specimen is recorded and given in the following table, calculate the man failure rate for a time period of 1000 hrs and the mean time to failure for all ten pieces.

Specimen	Time

1	900
2	910
3	925
4	930
5	950
6	962
7	970
8	975
9	980
10	1000

Solution

Problem 4

The results of tests conducted for 2000 safety valves manufactured by a firm are given in the following table. Time interval of test is for every 4 hr calculate failure density and hazard rate

UNIT –II

L1 – CLASSIFICATION OF MAINTENANCE APPROACH

Maintenance Approach

Breakdown maintenance planned maintenance

Preventive corrective predictive condition Reliability control

Maintenance maintenance maintenance based maintenance control maintenance

Breakdown Maintenance

in this system the equipment is allowed to function / operate till no failure occurs ie no maintenance work is carried out in advance to prevent the failure. As long as the equipment is functioning at a minimum acceptable level, it is assumed to be effective. This means the people wait till the equipment fails and repaisir. This approach of maintenance is ineffective and extremely expensive. The following factors contribute to high maintenance costs.

- Poor planning
- Incomplete repair

Limitations:

Most repairs are poorly planned due to time constraint caused by production and plant management . this will cost three to four times than the same reapir when it is well planned.

This approach focus only on repair or the symptoms of failure and not on the root cause of failure. This results only in increase in the frequency of reapir and correspondingly the maintenance costs.

For example when a bearing fails, it leads to production stop. By this approach only the bearing will be replaced with a nw one, but no attempt will be made to study the cause of failure or to present a recurrence of this failure. This

may seriously affect the relaiability of the system.

Breakdown of an equipment or machine or station in a system will have a significant effect on the production cost, quality and schedules. For each break down, one or more operatious that are to be performed by that particular machine/ equipment are idled, which in there delays the completion time of the job. Mean while, parts waiting for this equipment / machine are to be diverted and assigned to other competing machines. are to be diverted and assigned to other competing machines. because of this the cost of manufacturing goes up.

Corrective Maintenance

Corrective maintenance is the progress focused on regular planned tasks that will maintain all critical machinery and system in optimum operating condtions. The effectiveness of this program is judged on life cycle cost of critical equipment rather than on how quickly the broken machines are restored to working conditions. It is proactive approach towards maintenance management.

The main objectives of this program are to

- Eliminate breakdowns
- Eliminate deviations from optimum operating conditious
- Eliminate unnecessary repair
- Optimize all critical plant systems.

Presentive Maintenance

It is a maintenance program which Is committed to the elimination or prevention of corrective and breakdown maintenance. A comprehensive preventive maintenance program involves periodical edvaluation of critical equipment, machinery to delteet problem and schedule maintenance task to avoid degradation in operating conditions.

Benefits of Preventive Maintenance

In general the cost incurred towards breakdown maintenance is usually higher than the cost incurred on preventive maintenance.

It maintains the equipment in good condition to preventing them from bigger problems

Prolongs the effective life of the equipments.

Detects the problem at earlier stages.

Minimizes / eliminates the rewash/ scrap and help in reducing the process variability.

Significantly reduces unplanned downtime.

Predictive Maintenance

Predictive maintenance is a management technique that uses regular evaluation of the actual operating conditions of plant equipment, production systems and plant management functions to optimize total plant operation. It is not a solution for all the factors that limit total plant performance.

L2 – CONDITION BASED MAINTENANCE TECHNIQUES

- Vibration Monitoring – determins the actual condition of equipments / machines by studying the noise or vibration produced during functioning.
- Thermography – determines the condition of plant machinery systems etc by studying the emission of infra red energy ie temperature.
- Tribology – determines the dynamic condition of bearing lubrication, rotol support structure of machinery etc by adlopting any one of the techniques like lubricating oil analysis, spectragraphic analysis, fessography and wear particle analysis.
- Electrical Motor Analysis – determines the problem within motors and other electrical equipments.
- Visual inspection - determines the condtions of working elements visually based on the experience.

Realibility Centered Maintenance (RCM)

It is one of the well- established systematic and a step by step instructional tool for selecting applicable and appropriate maintenance operation types. It helps in hw to analyze all failure modes in a system and define how to prevent or find those failures early. The rough process of a CM is as follows.

Target products or systems of maintenance should be clearly identified, and necessary data should be collected.

All possible failures and their effect on target produced or systems are systematically analyzed.

Preventive or corrective maintenance operatious are considered selection of operations is done based on rational calculation of effectiveness of such operations for achieving required maintenance quality, such as reliability, cost etc.

Applications of RCM

When designing, selecting and installing new systems in a plant.

When setting up preventive maintenance for complex equipment and systems for which we are not clear on how they work.

When teaching people the basics of reliability it helps to explain the matters in a detailed fashion using RCM.

Total Productive Maintenance

The goal of TPM program is to significant increase the production, at the same time increasing employee morale and job satisfaction.

The aim of total production maintenance was to maximize plant and equipment effectiveness to achieve optimum life cycle cost of equipment.

Implementation of TPM

To implement an effective TPM is an organization there are certain stages to be planned and executed.

Stage I	-	initialization
Stage II	-	Introduction on TPM
Stage III	-	Implementation of TPM
Stage IV	-	Institutionalization

Stage I

Announcement by management about TPM. Joe level management people should attend awareness programs on TPM to have proper understanding, commitment and active involvement. Then all matters about TPM should be communicated to all others in the company.

- Initial education
- Setting up TPM departmental committees.
- Establishing TPM working system and target
- A plan for institutionalizing.

Stage II Introduction Stage

A grand ceremony is to be arranged inviting our customers, affiliated companies, sister concerns and communicating them that we care for quality.

Stage III – Implementation Stage

There are certain activities which are performed and known as pillars of TPM are carried out.

Stage IV Institutionalizing stage

Once the action are familiar with the TPM process and have experienced success with small level problems and then with high and complicated problems, the company can apply for PM award.

L3 – PI

LLARS OF TPM

TPM starts with 5, s principle. Problems cannot be clearly seen when the workplace is unorganized. Cleaning and organizing the workplace helps the tem to uncover problems.

5s Seiri – Sort out.

This means sorting and organizing the items as critical, important, frequently used items, useless, or ileins that are not need as of now.

Seiton – Organize

Each item has a place and only one place.. the items can be identified early by writing name plates and coloured tags. `

SEISO – SHINE

Their involve cleaning the workplace free of turss, grease, oil, waste, scrap etc. no loosely hanging wires or oil leakage from machines.

SEIKETSU – Standardization

Employees have to discuss together and decide on standards for keeping the workplace/ machines/ pathways neat and clean. These standards are implemented for whole organization and are inspected randomly.

SHIFTSUKE – Self Discipline

This is to bring about self discipline among employees of the organization. This includes weaving badges, following work procedures, punctuality, dedication to the organization etc.

Piller 2 – JISHU HOZEN

Also known as autonomous maintenance.

The pillar aims at developing operators capable of taking care of small maintenance tasks themselves, thus freeing up the skilled maintenance people to expend time on more value added activity and technical repairs

Pillar 3 – Kaigen

"Kai" means change "Zen means good. Means a continuous improvement will be there.

The above graph shows the continuous improvement.

Pillar 4 – Planned Maintenance

It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This maintenance classified into four "families or groups" which were dfined earlier.

Pillar 5 – Quality Maintenance

It is aimed towards customer delight by getting them from the highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner. We gain understanding of what parts of the equipment affect product quality and being to eliminate current quality concerns and then more to poleintial quality concerns.

Pillar 6 – Training

It is aimed to have multi-skilled employees whose morale is high and who are eager to work and perform all the required functions independentl and effectively.

Pillar 7 – Office TPM

It must be followed to improve, productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses.

Pillar 8 – Safety Health and Environment

This pillar aims at achieving

- Zero accident
- Zero health damage
- Zero fires.

L4 – TPM & TQM

Similarities

In many of the aspects, TPM is found to have similarity with the total quality management (TQM) program. The following are the similarities between them.

Empowerment of employees to initiate corrective action, bench marking and documentation.

Top level management committed to the program.

Long range outlook perspective.

Dissimilarities

Category	TQM	TPM
Objective	To have quality	To have reliable equipment
Means of achieving	Through systematized management	Through active participation of employees
Target	Minimized defective Preventive maintenance	Elimination losses and wastes.

The main objectives are to achieving zero defects zero accidents and zero breakdowns in all functional areas of an organization. Also the objectives include to create different team of people to have active participation aiming at minimization of defects and to inculcate autonomous policy.

Maintenance scheduling

It is a joint maintenance operations acitivity in which maintenance agress to make the resources available at a specific time when the unit can also be made available by operations. Resources include manpower, materials, tools and any special equipment.

The work scheduling should be aimed at to have least adverse effect on normal operating schedule while optimizing the use of maintenance resources – especially labours.

The success of any maintenance schedule depends on two basic

elements.

- Work should not be schedules which is not completely ready for scheduling, regardless of pressure.
- People from other operating units should be involved while creating the schedule.

Communication is the main key to establish successful maintenance scheduling.

This involves everyone from planners, schedulers, maintenance supervisor, craftsman, store room personnel. Any discontinuity in communication with heavily influence and drag down the success rate.

State holders and their role

In maintenance scheduling, the state holders belong to various departs, sections of the company. For the scheduling to be effective, it is essential to ensure a sound communication among the state holders. Each one of the state holders in the communication chain has a role to play, which are to be clearly defined and the should be made aware of it.

1. Planner

The work is property planned with respect to customer requirements, shores material \, directly purchased material and special service mentioned on work order. Also the work to be carried out with the time of safety requirements should be described.

2. Schedules

He should ensure that

- Trades are available to conduct the work during the schedule duration.
- Materials and / or service availability
- Communicating the details of the above to person involved in

maintenance and operations.

3. Maintenance Supervisor

He / She will be responsible for the day to day activities comprised in weekly schedule and also determines the business availability. They attend to specific such as to who- what – where – when.

4. Craft Man

She executes the assigned task and keep informing the maintenance team, the outcome as well as any practical difficulty in their part, for any further analysis.

5. Storeroom personnel

They maintain the records of receipt of goods and notify if any damage exists.

6. Operations Superintendent

He must be kept informed in advance about the equipment condition. Since he is well aware of production schedule, should determine the opportune time with maintenance to release the equipment.

7. Operator

He is the person responsible for securing the equipment and report back to maintenance personnel if any elevation is observed.

- Job plans providing number of person, required, lowest required craft skill level, craft work hours per skill and job duration information and necessary for advanced scheduling.

- Weekly and daily schedules must be adhered to as closely as possible. Proper priorities must be placed on new work orders to prevent interssuption of these schedules.

- A scheduler develops a one – week schedules for each crew based on craft hours available, forecast that shows the highest skill available.

- The one – week schedule assigns work for every available work hour.

The schedule allows for emergencies and high priority, reactive jobs by scheduling a significant amount of work on the easy interrupted tasks.

- The crew supervisor develops a daily schedule one day in advance using current job progress, the one-week schedule and new high priority reactive job as a guide.
- Wrench time is the primary measure of work force efficiency and of planning and scheduling effectiveness. Work that is planned before assignment reduces unnecessary delays during jobs and work that is scheduled reduces delays between jobs.
- Schedule compliance is the measure of adherence to the one – week schedule and tis effectiveness.

L6 – REPAIR

Generally, the maintenance scheduling embraces the following activities.

- Inspection
- Repair
- Overhauling

Hence the term repair does not reflect the actual but only the time duration

consumed to perform the corrective action. Based on the time the repair may be minor one like adjustment of fasters, adjustment of belt tension, etc, or major one like un conditioning the bed surfaces, guide ways and cleaning of bearings etc.

To create maintenance scheduling program, the various maintenance activities may be classified into four categories which are as follows.

- Inspection (I)
- Minor Repair (R)
- Medium or major (R2) and
- Overhauling (O)

Repair cycle

The repeated performance of all/ some of the above mentioned activities in sequence between successive overhauling is termed as Repair cycle”

The figure shown below shows the activities to be carried out during overhauling of equipments.

It is clear that first an inspection activity is scheduled followed by minor/

major repair activities. Then an inspection takes place followed by a major reapir. Again a second inspection is followed by major repair. Like this is goes and completes one reapir cycle. The set of there activities between two conseeutive. Overhauling is defined as a repair cycle. This typical repair cycle covers three inspection and two minor and major repair activities. This can be represented o1 – I1 – R11 – R21 – I 2 – R1 – I3 R2

From the above it is understood that the repair cyle is mainly time dependent between activities

An index number generally known as repair completely number is used to devote the complecity repairing equipments. More the complexity number more will be the activities involved and in turn more staffing requires to complete the repair cycle.

L7 – LUBRICATION

In industrial equipments / machineries, the surface of the mechanical parts will have physical contact on the neighbouring parts to establish a relative motion between them.

During the operation of the equipments, those contacting surfaces are subjected to friction which depends on the are a of material, properties of material etc which in undesirable. This leads to progressive damage resulting in material loss which is defined as wear. Friction and wear also generate heat and responsible for the overall loss in system efficiency. All these contribute to significant economic costs due to equipment failure, cost for replacement and downtime.

The primary objective of lubrication is to reduce wear and heat between contacting surfaces in relative motion. By means of lubrication co efficient of friction (which depends on area of contact and amount of load acting). Could be reduced and intern heat and wear of the surfaces.

Lubrication also aids to

- Reduction of rust formation
- Reduce oxidation
- Transmit mechanical power into hydro fluid power systems
- Seal against clust, dirt and water.

Selecting the light and right lubricant, the sight amount of lubricant and the correct application of the lubricant are essential to the successful performance of any bearing, because bearing lubricants serve three purposes.

Reducting friction by separating mating surfaces.]

To transfer heat (with oil lubrication)

To protect from correction and with grease lubrication, dirt ingress.

The success of there three factors depend heavily on the film thickness on the raceway and at the sit / roller end contact.

LUBRICANTS

Any method or material used to reduce friction with high coefficient of friction, by establishing low- discus film are called lubricants. Lubricants are available in liquid, solid and gaseous forms. Solid lubricants (soap, mica, molybdenum disulfide etc) are used for industrial applications when oil or grease are not suitable. Graphite is used when the loading at contact points is heavy.

Methods of Lubrication

The following are the various methods of lubrication normally used for industrial applications.

- Hydrostatic lubrication
- Hydrodynamic or Fluid film lubrication
- Boundary Lubrication
- Elasts hydrodynamic Lubrication (Ehd)
- Extreme pressure (EP) lubrication.

In general, the method of lubrication is characterized by the friction and wears characteristics of wearing surface. Based on the value of “R” which is defined as follows, the method of lubrication is chosen.

R = Mean Fluid Film thickness/ surface roughness (CLA)

Where R is less then or equal to 1 for

Boundary lubrication

R is inbetween 5 and less than or equal to 100 for fluid film lubrication.

R is between 1 and 5 for mixed lubrication.

Lubricamts are available in liquid, solid and gaseous forms. Graphite is used when the loading at the contract points in heavy.

L8 – HYDROSTATIC LUBRICATION

In hydrostatic lubrication systems, a their film of lubrication is created between the journal and the bearing by supplying lubricant under pressure with an external source like pump. Since the lubricant is suppolied under pressure, this type of bearing is called externally pressurized bearing

Compared to Hydrostatic bearing, hydrodynamic bearings are simple in construction, easy to maintain and lower in initial as well as maintenance.

2. Hydrodynamic or Fluid film lubrication

In heavily loaded bearings such a thrust bearings and horizontal journal pressure is also required to support the load until the film is \established.

If the pressure is generated externally is called as hydrostatic lubrication and if generated internally in within the bearing by dynamic action, it is referred to as hydrodynamic lubrication. In this type of lubrication, a fluid wedge is formed by the relative surface motion of the journals or the thrust runners over their bearing surfaces.

a. Thrust Bearings

* in hydrodynamic lubrication, the wearing surfaces are completely separated by a film of oil. This type lf lubrication is similar to moharized speed moving on water.

When not moving the boat begains to move, it experiences a resistance due to the iscosity of water.

This cause a slight life of leading edge of the boat and allows a small amount of water between it and supporting water surface.

As the velocity of boat increases, the wedge shaped water film increases until a constant velocity is reached.

When the velocity is constant the amount of water entering the leading edge equal the amount passing outward from the trailing edge.

For the beat to emain above the supporting surface there should exist a upward pressure equalists the laod. The same principle can be applied to sliding

surface.

The operation of thrust bearing is an example of hydrodynamic lubrication. Thrust bearing assembly used in hydropower industries are also called ltilt pad barings.

The pads of these bearings are designed to lift and to tilt to provide enough area for lifting the load of generator. As the thrust runner moues over the thrust shoe, fluid adhering to the runner is drawn between the runner and shoe forming a wedge of oil.

As the velocity of thrust runner, increases the pressure of oil wedge and the runner is lifted as full fluid film lubrication takes place. When the load high the pressure pupms are used to provide initial oil film.

Extreme Pressure Lubrication

Antiwear agents (chemicals) which are normally used in boundary lubrication will not be effective beyond certain temperature (250 degree Celsius).

In heavy loading applications oil temperature raises behond the anti-wear protection.

Under this situation lubricants containing additincs that protect against extreme pressure called EP lubricants are used.

EP lubrication can be adchieved by chemical compounds of phosphorus, sulplur, chloride or combination of these.

L9 – JOURNAL BEARING

The operation of a journal or sleeve bearing is also an example of hydrodynamic lubrication when the journal is at rest its weight squeezes out the oil film so that the journal directly rests on the bearing surface. During operation, the journal has the tendaency rollup the side of bearing. So the fluid adhering to the journal is drawn into contact area and when the speed increases an oil wedge is formed, which is shown in the drawing shown above.

The pressure of the oil wedge increase until the journal is lifted up vertically but also pushed to the side by pressure of oil wedge.

Then the journal is rotating at a constant velocity, film thickness will exist only at the left counter and not at the bottom of the bearing.

Elasto – hydrodynamic (EHD lubrication)

The lubrication principle is applicable to rolling bodies such as tail or roller bearings, is known as EHD lubrication.

The formation of the lubricant film between mating bearing surfaces is called elasto – hydrodynamic mechanism of lubrication.

The two major considerations in EHD lubrication are the elastic deformation of the contacting bodies under load and the hydrodynamic effects forcing the lubricant to separate the contracting surfaces while the pressure of the load is deforming them.

The contact between the large end of the roller and the inner race it is called elasto – hydrodynamic contact or a hydrodynamic contract. As the rit / roller loads are much lower than the roller / race loads, the film at the rit/ roller and contract is usually twice as thick on the roller / race contact

However, scoring and welding amy still occur in severe conditions, including high speeds, viscosity, load or inadequate lubrication, in there conditions, a lubricant with extreme (EP) pressure additines is to be used to prevent bearing damage.

Even though the lubrication principle of rolling object is different from lsiding objects, the principle of hydrodynamic lubrication can be applied upto

limits.

An oil wdge similar to hydrodynamic lubrication eaists at lower leading edge of beaing. Adhersion of oil to the sliding element and support surfaces increases pressure and creates an oil film between two surfaces.

Since the area of contract is extremely small in a roller bearing or ball bearing , the force per unit area will be extremely high. Under this pressure, it would appear that the oil could be squeezed from between the surfaces. The viscosity increase and prevents the oil from being entire squeezed out.

Unit III

UNIT – III CONDITION MONITORING

It is one of the maintenance methods which are used to assess the health and conditions of equipment, machines, systems or process by absorbing, checking, measuring and monitoring several parameters. This technique is also called as equipment health monitoring (EHM).

Key features of condition Monitoring

The key features of effective condition monitoring system include the following:

(i) Links between cause and effect:

A clear relationship mostly exists between the measurement being taken and the condition of the equipment.

(ii) System with sufficient response:

The monitoring system must respond quickly enough to provide borning of deterioration in machine condition for appropriate action to be taken.

Benefits out weighting Cost

The benefits of performing condition monitoring to predict equipment condition must outweigh the implementation and running cost.

Data Storage and review facilities

A system for measuring and recording data must exist to enable the

condition of equipment to be predited.

Fundamental steps in Condition Monitoring

An effective condition monitoring system follows the following basics steps:

- Identifying critical systems
- Selecting suitable techniques for condition monitoring
- Setting baselines / alerts
- Data Collection
- Data assessment
- Fault diagnosis and repair
- System review

Types of Condition Monitoring

There are three types of condition monitoring as follows:

(i) Subjective Condition Monitoring:

Here the monitoring personnel use their perception of senses and judgment to note any change of the condition. The guidelines or hints where to book for leakage, bearing play etc. posture or figures illustrating different conditions of components may also be helpful.

(ii) Aided Subjective or condition monitoring with simple gadgets:

Here the monitoring personnel are simple gadgets to add their ability to perceive conditions better. Theregadgets are discussed more in detail in the objective condition monitoring.

(iii) Objective condition monitoring:

Different instruments and facilities are used for obtaining data giving direct measure of the parametric condition of the components even while the machine is working.

Advantages of Condition Monitoring

- Improved availability of equipment
- Minimized breakdown costs
- Improved morality of the operating personal and safety.
- Improved reliability
- Improved planning

Disadvantages

- Gives only marginal benefits
- Increased running cost
- Sometimes difficult to organize

Cost comparison with and without condition monitoring.

L2- Methods and Instruments for Condition Monitoring

Types	Methods	On / Off line	comments
Visual inspection	Human Eye	On / Off Off	• It covers a wide range of highly effective condition checking and surface inspection methods. • Can be used for internal inspection of machines, good for detecting surface corrosion, wear and severe defects line cracks.

Vibration Monitoring	Overall vibration level	On	• Represents the vibration of a collating or reciprocating machine as a single, number which can be trended and used as a bases for the detection of common machine faults. • Represents the vibration of a rotating or reciprocating machine as a frequency spechrin. • A variety of vibration based techniques exists for the detection and location of structural faults. The majority of such techniques involve imparting a known vibration into the structure and analyzing the resulting response.
	Frequency analysis	On	
	Structural Monitoring	Off	
Temperature Monitoring	Temperature crayons, paints	On	• Simple and effective aids to visual inspection. • Range from stock-on thermo metric strips to permanently installed thermocouple sensors. • Non contacting device which measure radiated body heat to estimate the surface temperature of a component.
	Thermometers	On	
	Infra – red meter	On	

Lubrication analysis	Magnetic plugs & filter Ferrography Spectroscopy	On / Off N / A N / A	• Analysis of debris picked up by plugs or filter in an oil washed system. • Analytical technique used to separate ferro detris by size to enable microscopic examination. • Analytical technique is used to determine the chemical composition of the oil and debris.
Crock Monitoring	Dye peretrant Magnetic flues Electrical resistance Eddy current Ultrasonic	On / Off On / Off On / Off On / Off On / Off	• Detect cracks which break the surface of the material. • Detects cracks at / near the surface of ferrous materials. • Detects cracks at / near the surface and can be used to estimate depth of crack. • Detects cracks near to surface. Also useful detection of inclusions and harness changes. • Detects cracks anywhere in a component.

Corrosion monitoring	Weight loss coupon Incremental bore holes Electrical resistance	Off On On	• Coupons are weight and weight loss is equated to material thickness loss due to corrosion. • A series of five plugged holes of incremental depth which are periodically unplugged and scrutininized for leakage. • Electrical element and potentio meta are used to assess resistance change due to material loss. Capatle of detecting material thickness reduction of loss than one millimeter .

L3 Visual Condition Monitoring

The visual condition of the components located at inaccessible locations is to be monitored, may be with respect to corrosion or fatigue cracking or even dust / sediment collection that is deleterious to the functioning of the component.

Inspection mirrors

They are used inspect crences, dark spot, inside of narrow mouthed cylondess, or the pipes of heat exchanges or loilers.

These mirrors can be simple like that of a dentist or,

- With adjustable mirror angle controlled by a wire running along the holding rod.
- Illuminated with a light bulk near the mirror of special use in dark spots, inside cylinders or inside heat exchanger pipes.
- With telescope rod, for adjusting the length of the gadget.
- Mirrors filted inside a small tube ratter than on a rod to prevent damage to the mirror during inspection or insertion or operation.
- Perscope for specialized application or to assist the viewer etc.,

Endoscope

- These are like barescopes, but are flexible.
- They work on the principle of image transfer by total internal reflection in a lundle of glass fibres.
- Alro called optical fibroscopes, they are flexible and more versatile in several applications.
-

Vibration monitoring

Introduction

- It is the motion of a machine or machine part, back and forth form its position of rest.
- It is essentially the heart beat of all mechanical equipment.
- The analysis of vibration signals, produced during the operation of the

machinery, pounds important information about the condition of the machinery.

Fundamentals of Vibration:

It is defined as the cyclic motion of rotating or reaprocating machine, back and forth from its position of rest.

The four forces inrohed when vibration happens are

- The exciting force such as unbalance or misalignment.
- The mass of the vibrating system.
- The stiffness of the vibrating system
- The damping characteristics of the vibrating system.

Some of the more common problems which are known to produce vibrations are as follows.

- Imbalance of rotating parts.
- Electric components
- Misalignment of couplings and bearings.
- Bent shafts

- Component looseness
- Worn or damaged gears
- Bad anti frection bearings
- Torque vibration
- Auodynamic forces
- Hydraulic forces etc

All of these causes can be reduced to one, or more of five different types of problem. That is parts will be either unbalamed, misaligned, loose, electric or reacting to some external force. The cause of vibration must be a force which is changing in either its magnitude or in direction.

L4 Vibration Monitoring Techniques

There are number of vibration monitoring techniques available today. The various techniques can be broadly classified under the categories shown below

The time domain analysis

In time domain analysis, the time history of the event is recorded for further analysis. Several time domain techniques have either been proposed or have been used in machine condition monitoring and this is represented below

Waveform analysis consists of recording the time history of the event on a storage oscilloscope or a real time analysis. By using this a discrete damage occurring in gears such as broken teeth on gears and cracks in the inner and outer races of the bearings can be identified relatively easily.

The frequency domain analysis

Digital fast fourier analysis of the line waveform has become the most popular method of derived the frequency domain signal. Various frequency domain techniques can be related as shown below.

Temperature monitoring

Introduction

Temperature is defined as a measure of velocity of fluid particles. It is a property which is used to determine the degree of holmess or coldness or the level of heat interrity of a body.

Instruments for measuring ordinary temperature are known as thermometers and these measuring high temperature are known as pyrometer.

On large engines, sir handlers, brilers, terbinede temperature transducers are included for all major bearings some packages include shut down circuits and alarms of temperature gets above certain limits. The hardware for infrared is becoming more and more powerful. An infrared gun take sopt temperature without imaging capacity.

The techniques used in such monitoring may be one or more of the

followings.

- Temperature crayons & tupes.
- Thermometer and optical pyrometers.
- Softening comes / wave paints.
- Bimetallic strips
- Thermocouples and fusible plugs
- Thermisters
- Thermo diodes and thermo resistors.

Temperature crayons and taps.

Temperature monitoring by feel of hand or by simple measuring items / instruments, like thermometers, temperature crayons and tapes etc is an age old practice of finding out depects or defetire components. The subjecture of temperature monitoring is touching the moter etc,and assessing if oner. Also temperature stickers are the most common and cost effectives.

L5 Thermo – diodes & thermo – transistors

a) Thermodiides

It is a widely use method for measuring temperature. When the temperature of doped semiconductors changes, the mobility of their charge carriers changes and this effects the sate at which electrons and holes can diffuse across a P.N.Junetion. the difference in voltage and current through the junction is a function fo the temperature.

b) Thermo Transistors

in thermo-transistor the voltage across the junction between the base and the emilter depends on the temperature. A common method is the use of two transistor with different collector currents to find the difference in the base emitter voltage between item. The difference is the measure of temperature.

It can be combined with circuit components on a single chip to give a temperature sensor as shown in the figure above.

Infrafed Thermography.

This technique uses the distribution of surface temperature to assess the structure or behavior of what is under the surface. It is non contact sensing method concered with the measurement of radialet electromagnetic theory. The enery emilted by a surface at a given temperature is called spectral radiance and it is the property conceerved with emissinty.

Types of thermography

- Passive thermorgraphy

  The temperature difference (T) of 1 to 2ºc is generally found suspicious. A T of 4ºc value is a strong evidence of abnormal behaviours. In most of the applications, passive thermography is ralter qualitative since the goal is simply to pinpoint of the type go / no – go.

Active thermography

It is an externally applied thermal stimulation is needed to generate meaningful thermal constrasts that will yield to the detection of sub surface abnormalities.

Methods of observation.

The two methods of observation possible are reflection and transmission.

In reflection, greater resolution is obtained but the thickness of the material inspected is small.

In transmission a greater thickness of material can be inspected but the depth information is lost since the thermal front has the some distance to travel whether or not its strength is reduced by the presence of a defect.

The resolution is weak in transmission hence it is necessary to use more sensitive detection equipment. The approach in reflection is good for detection fo defects located closer to the heating surface while the transmissive approach reveals defects located to the near surface.

Worling of infrared themography.

The infrared (IR) comera is the central piece, if surface emissivity is sufficiency high, relevant temperature difference on the surface being tested can be measured.

L 6 Lubricant Monitoring (or) Lubrication Oil Analysis

Introduction

- The lubrication oil in any system is often required to perform a number of functions such as to reduce friction to cool components and to clean load bearing surfaces.
- Over the time the oil is likely to degrade losing its lubrication properties due to chemical breakdown and becoming contaminated by the ingress of collates fuels and other lubricants.
- The properties of the oil can be monitored in a number of ways acidittity for oxidation viscosity for lubrication flash point for contamination and chemical composition for chemical degradation.
- In addition to the oil properties the presence of wear particles in the oil can also be used to predict a number of faults by observing their size, quantity, shape and material composition.
- These particles may be caused by year ingress (failure or filter) or corrosion of components .
- The chemical analysis of particles can often identify particular component which are foiling for example, if silicon is found in the oil then a breach has occurred between the outside and the lubricating systems.
- Lubricant analysis is an important and to condition monitoring.
- Laboratories recommended that samples of machine lubricant be taken as scheduled intervals to determine the condition of the lubricating film that is oritical to machine train operation.
- Oil monitoring is an extremely effective tool for assessing the condition of the oil itself and the components with which the soil comes into contact.
- It is particularly useful in equipment where vibration analysis is difficult to carry out perhaps where components are remote from possible transducer mounting points.

Test on lubricating oil

Typical tests are conducted on lubricating oil samples as given below:

1. Viscosity

Due to internal friction every fluid has a resistance to flow called viscosity. A lubricants viscosity is measured at either 40c or 100c.

2. Oxidation

It is caused by a lubricants natural tendency to bond with oxygen. It is a chemical change that presents the oil from performing its job.

3. Nitration / sulfation

It occurs as a portion of the engine exhaust gets ingested back into the cranlecase and the lubricant bonds with the gases forming sulfates and ritrales.

4. Glycol

It is an index of how much fual antifreeze / coolent in the lubricant.

5. Fuel dilution

It is an index of how much fuel is in the lubricant and indicates the condition of the pistion rings and fuel infection system.

6. Total Base Number (TEN)

It is a measure of the reserve alkalinity in engine oils.

7. Oil contamination

Oil contamination by water can cause major problems in a lubrication system. Water will also accelerate corrosion reaction.

L 7 Crack Monitoring

It is mostly used for quality assurance and metallographic analysis to assess the quality of metals and quality of procedures during making, shaping and breaking of metals in industries.

Crack monitoring program does not measure total crack depth and width but change in crack width. This change in crack width is called crack displacement the crack displacement measured by the sensors may be driven by any combination of the factors listed below

- Differential thermal expansion
- Structural changes in various components of machine
- Strinchage and turisting of different components temperature and humidity changes etc

- Fatigue and aging of components etc.

NDT plays important role in crack monitoring. NDT is defined as a method of inspecting on object without impaling its future usefulness major methods include:

- Penetrant testing
- Magnetic particle testing
- Ultrasonic testing
- Radiography testing

There are also some ranges of other new techniques that have particular specialized applications in limited fields. They include

- Eddy current testing
- Acoustic emission methods
- Thermography
- Holography
- Leak testing

Liquid Penetrate Test

Introduction

The liquid penetrate test is one of the oldest methods of non destructive testing. It is based on the old oil and whiting process formerly widely employed on steel parts particularly in the soil road industry.

Development of liquid penetrant list:

Techniques often then wiping have been found to remove the excess surface oil or penetrant from test objects. Agents often then whiting were found to develop and exhance the flow indications.

When to use liquid penetrant list

Liquid penetrant inspection detects only those discontinutive that are present on or are open to the surfaces of the part. Therefore of only surface defects are of interest, liquid peretrant process may be used in the following

situations

- When the test material is a nonmagnetic metal (such as titarium, aluminium etc)
- Or non metallic materials (such as plastics or ceramics)
- When the geometry of the part is such that the shape itself may hide (of surface defects) produced by another non-destructive test techniques.
- When the size or shape of the surface defect is such that it can escape detection by other techniques.
- When parts are to be inspected in locations where electric power is not available, or is too expensive or too inconvenient to use, or where the use of electricity creates of safety hazard.

Basic procedure for liquid penetrant inspection:

The procedure of penetrant inspection is quite simple. The penetrant (or inspection liquid) carriers a visible or fluorescent due tracer in a penetrating liquid vehicle.

L8 Magnetic Fluse Testing

Magnetic particle testing (MT) is a non destructive testing (NDT) method for detecting discontinuitives that are primarily linear and located at or near the surface of ferromagnetic components and structures.

Ferromagnetic metals are those strongly althracted to a magnet and can become casily magnetized examples include iron, nickel and cobalt.

Paramagnetic metals such as bestenitic strainless steel are very weakly attracted by magnetic forces of alteration and connot be magnelized

Diamagnetic metal are very slightly repelled by a magnet and cannot be magnetized. Examples include bismuth, gold and antimony.

Only those metals classified as ferromagnetic can be effectively inspected by MT.

Requirements of surface conditioning:

Preparation

Salisfactiory results are usually obtained when the surface are in the as welded, as rolled as forged condition.

Prior to magnetic partick examination the surface to be examined and all the adjacent areas within atleast 2.5mm shall be dry and free of all dirt, grease, lint, scale, welding flase and spatter , oil or olter extraneous matter that could interface with the examination.

Cleaning may be accomplished using detergents and organic solrents, paint remoness, rapoure degrearing sand.

Surface contrast exhancement

When coatings are supplied tempearily to concoated surface only in amounts sufficient to enhance particle contract, it must be demonstrated that the indicatious can be detected through the enhancement coating.

Procedure / Technique

The examination procedures shall be bored on the following information:

- The material, shapes or sizes to be examined and the extent of the examination.
- Magnetization techniques to be used
- Equipment to be used for magnetization
- Surface preparation (finishing & cleaning)
- Types of ferromagnetic particles to be used manufacturer, colour, wet or dry etc.
- Magnetization crurrents (type and ampuage)
- Demagnetization
- This method can be used for the detection of defects which break the surface or close to the surface of the ferromagretic materials. When a ferromagnetic component is magnetized, any discontinetity that is approximately at right angles to the magnetizing field direction will distort the magnetic field lines and if at the surface or close to the surface will

result in the formation of a leakage field.

Magnetic Inspection

The magnetic field in a material is generally produced by passing a heary current through the component by placing it in a coil through engine / which a current passes or making it part of metals or metals or metal oxides, its then sprayed over the surface, either dry in air or a gas or wet on some liquid suspension.

L9 Leakage Monitoring

Leakage is unintended discharge or oozing of fluids and gases from mechanical components, occurring because of,

- Increase in clearance or ear out or
- Exesion of parts like value seats, poppets and spools etc or
- Damage of seals and packing or
- Incorrect selection / filting of seals and components or
- Other reasons

Leakage are both external or internal external leakage are relatively easy to detect as some fluid or gases flow out of leaking components. Internal leakages are little difficult to detect as the leakage fluid / gas goes back to reserroir directly or through esting pipelines and is normally not seen following outside.

For detecting fluid leakages of underground pipelines, on crude method is that the area around the leakage gets wet and the fluid starts coming / oozing out from any soft location. Few sensors are connected at some distance for timely indication of leakages for very long times. In some cases, pressure drops are also indicated by leakages.

Leak testing methods can be classified according to the pressure and fluid (gas or liquid) in the system. The commonly used leak testing methods are

- Acoustic
- Bubble testing
- Flow detection
- Specific gas detectors
- Quantity loss determination etc

Direct sensing in gas system at pressure is done by acoustic method, bubble method or flow detection.

Specific gas detectors like sulphur hexafluoside, halogen, thermal conductively, mass spectrometer (helium) leak detector etc. are also used to detect and quantify the leaks for the components at pressure or at vacuum. The major factors that determine

UNIT –IV

L1- Repair methods for basic machine elements

Failures:

Even though the meaning of the terms “defect” and failure are identical, defect is used in border perspective. But in general the term failure refers it malfunctioning, stoppage, crash and deterioration etc of any equipment or system. As regard to industrial scenario the term failure may defined as one of the following

- Any loss that interrupts the continuity of production

- A loss of asset availability
- The unavailability of equipment
- A deviation from the status quotation
- Rot meeting target expectations
- Any secondary defect

There may be many factors cause mechanical failure of equipment /system in industries

As regard to industries it can be said that the cause of failure of an equipment /system may fall under any one of the following categories

- **Unexpected and unintentional damage-**bearing seizure, gear with breakage etc.
- **Workmanship-**unskilled undivided and rot motivated
- **Design-** improper design which does not meet the requirement and working conditions.
- **Material-** manufacturing defects, mishandling and storage etc.
- **Operation-**incorrect usage of equipment etc.

Failure models:

It is clear that generally the causes for failure may be predictable and sometimes may not be possible. So failures are classified as either predictable or unpredictable, in order to select the best possible maintenance program.

Predictable failure model (age- dependent failures)

Time dependent failures are called age dependent failures. A simplified model of age dependent model is shown in the graph given below

Unpredictable failure model (purely random failure)

It is experience that most of the components would reach a

point of work out failure at the time of its old age, which a quite common phenomenon similar to age-dependent failure, the following graph given below that the cause of failure will be random in nature**.**

L2-Running –in-failure (an early-failure model)

suppose if some components/equipments are installed with unnoticed defects, may fail in a short duration after installation than during its useful life this kind of failure behavior results in exponential pdf of time-to-failure. This by constrast with the negative exponential pdf shows a single exponential fall off. They are initial repaid exponential fall and later slower exponential fall as shown in the persion graphs

failure analysis:

in principle defect or fault analysis are normally follow similar approach in any industrial maintenance system.

Fault tree analysis(FTA) is another technique for reliability and safety analysis bell telephone laboratories developed the concept in1962 for the U.S Air force to use work the minute man system.

It was later adopted and extensively applied by the being company. Fault tree analysis is one of many symbolic “analytical logic techniques” found in operations research and in system reliability other technique include reliability block diagrams.(RBDS)

Deliration of FTD:

- Fault tree diagrams (or negative analytical trees) are logic block diagrams that display the state of system (top event) in terms of the states of its components.
- Like reliability block diagrams (RBDS) fault tree diagrams are also a graphical design technique and as such provide an alternative to wetherdology to RBDS.

- An FTD is built top down and in term of event an blocks.
- Rather than blocks.
- It uses a graphic “model “of the pathway within a system that an lead to a foreseeable, undesirable less event (or a failure)
- The pathway interconnect contributory events and conditions, using standard logic symbols (AND,OR etc)
- The basic constracts in a fault tree diagram gates and events, where the events have an identical meaning as block in an RBDS and the gates are the conditions.

Difference between fault trees and reliability block diagrams

- fault tree works in the “failure space” and looks at system failure combination
-

UNIT- V

L1- Material handling equipment

Material handling equipment:

It involves the movement of materials, manually or mechanically within the plant it is a mechanical device for handling of supplies in the greater ease and economy.

The movement may be horizontal, vertical or combination of both. MHE refers to various materials handling equipments like carts, hand trucks, false lifts, conveyers and also not limited to self pictures, motorized pullet jacks, track and other specialized industrial tracks powered by electric motors internal combination engine.

Need for maintenance of material handling equipments:

It eases the usage of manual handling and enhances operational effiency. In today's economic clomate of high labour and capital equipment cost, unexcepted machine failures and malfunctions can seriously and regatively imfact company profits. The breakdown, failure or malfunction of material handling equipment can cost a company time and money material handling maintenance program for MHE will help to maintain the high efficiency and keep it in running contition this also reduce the cost of expensive repairs as a result of a breakdown or unnecessary wear, enhanced productivity due to lease machinery downtime and reduction in the potential for personal injury

Maintenance of material handling equipments

The proper maintenance of material handling equipment is extremely essential for preventing the occurrence of bottle neck or points of congestions production line flow can be maintained only if the material handling equipments is in proper working order. Out of

money maintenance techniques available preventive maintenance is one of the best maintenance techniques suggested in case of material handling equipments.

Preventive maintenance helps to keep the material handling equipments always running conditions there by minimizing the interruption duing operation. A periodic inspection and minor alignments may be adequate to prevent the equipment breakdown. Preventive maintenance also includes lubrication adjustment and repaire.

There are three stages of preventive maintenance and they are

- Inspection
- Repaire and
- Overhaul

Maintenance strategies for hoists and cranes.

Portable cranes:

The major issues covered in maintenance of portable cranes are:

- It is necessary to keep loads within design limits on portable cranes that are mounted on wheels or wheeled platforms
- Frequent inspection of cralus, load hosting and lowering mechanism.
- Inspection of boone, base and platform for any sign of store e.g crachs, bends, breaks.

Overhead cranes:

the major issues covered in maintenance

- Keep the attachment in overhand crane loaded within the rating capacity.
- Maintain safety factors for replacement pasts according to manufactures specifications.
- Check welded connection(e.g main chords and other structural items) for crachs, bends, abrasion and corrosion

L2-stages of preventive maintenance cranes

Inspection:

All parts, open or covered are infected for wear and tear, worn out or unworkable components like wire ropes, wheels, hearings, both etc are removed. Breaks are adjusted and necessary lubrication applied.

Repaire:

The repairable parts of the system after inspection are corrected for small repaires and minor refects arre rectified. Systems like open gear transmission, coupling, riveted and lotted joints, trolley, breaks, guareds etc may be repaired according to the needs.

Overhaul:

It involves dismantling the complete mechanism and replacing all damaged components, crane strutive, buffers,rails, open gear transmission pulley blocks, etc may be replaced and various sub mechanism may be aligned and adjusted to ensure smooth operation

Maintenance chategies for conveyors:

The major issues covered in maintenance of conveyors are:

- **Conveyor system** need to be inspectd on a regular basis. The important areas include edlers, bearings, chains and belts. All of there morning parts are selected to wear and tear.
- **check conveyors** detect any belt slippage, dragging or defecture welars
- **frequently overlooked** are conveyor rolters, belts, chains regular maintenance procedure. So proper attension is repaired for the same.
- **Moring equipment parts** are subjects to blocks caused by metrial fatigre loose bearing and obstractions.
- **Checks conveyors** regularly to detect any belt slippage dragging a defective rolkers. Control static electricity through

bonding and grounding to minimizing static charges.

Stages of preventive maintenance for conveyors:

- **Inspection:**

  Belt or rollers are inspected for tensions, user and tear gear box properly lubricated, various fasteners are lightened and safety guards are checked.

- **Repair :**

  Rollers and belts are checked adjusted or repaired couplings, packing, safety guards, steal structures, gear transmission, learning joorts, threaded components etc are adjusted or repaired as per their condition and requirements.

- **Overhaul:**

  The conveyor system is completely dismantled components, wornout and beyond repair item like belts, bearings, packing, oil, sealers, rollers, drancs, fasteners and and coupling are replace

  Structures and safety guards may be repaired as per their conditions.

  L3-A typical scheduled conveyor maintanence plan

  - Check/lutricate all bearings,universal joints and pulleys
  - Check chain tension, wear and lubricate
  - Check sprocket alignment wear and screw set
  - Check flat belt tension, wear and lacing
  - Check v-belt tension wear share alignment
  - Check electrical connections at conveyor

- Check box and fill with lubricant to proper level
- Check general condition of system
- Operate entire system after service
- List any items requiring replacement or repair

Forklipts:

The major issues coraed in maintenance of forklipts are:

- **Forklifts** require a daily inspection for proper operation. Daily checks should wheels, brakes, forks, chains, hydraulics, steering horn & fuel.
- **fork lifts** with engine should be checked for coolant and engine oil levels.
- **forks** are subjected to jolts,atrranion, overloading etc which may reduce the lticleaness of blaks bend or burist them and cause fatigue cracks in areas of high stress concentration. Inspect truchs carefully for signs of excessive were and tear
- **remore accumulations of grease dirt**
- **scheduled** maintenance hased on engore hour or motor hour experience may reduce malfunctions.
- Gare special attension to breaks limit switches,trolley wheels, loadd hocks, castes and chairs. These needs to be examined for evidence of wear, malfunction, damage and proper operation.
- **Inspect sheares ruts, bolts,clamps, braces, hooks** and scrilar parts monthly or more frequently. Depending upon usage

A typical scheduled lift maintenance plan

- Check all safety devices on unit, such as up/down limits,door switches, pressure relief value etc
- Clean all debirs from the pit or from the victrity of floor

mounted units in order to avoid interference with the lift mechanism or rollers.

- Check for presence and proper setting of all snap rings and chips on axles, cylinders and rollers.
- Check rollers,pins and bushings for any signs of wear such as flat spots, missing fasteners,or dislodged bearing material.
- Inspect all welds under and around the left or fatigue or failure particularly inspect thestructural welds
- Check the hydrautic fittings for crachs or leaks and clean up any seepage on or benefit the cylinders.
- Check hoses and electrical limes for astrorions other abuse and check for snug connectors.
- Semi-annualy, change hydraulic fluid in cylinders.
- Check general condition of the lift.operate the lift after service.ched for any abnormal roles or vitrations.
- List any items requiring replacement or repaire.
- In addition to the wheels, the surface on which equipment is operated needs to be respected.
- Rough areas, crachs, pot holes,or brollen concrite are need to be identified and repaired.
- Floor surfaces, when improperly maintained, create problems for all types of material handling equipment in addition to slip, trip and fall hazards.
- These conditions can cause an accident resulting in damage to the material or to the werler operating the equipment.
- The hazards may be controlled by using correct surfacing/cleaning methods and materials.

- Schedule repair for cracks and other damage, repair holes should be carried out immediately

Check jacks:

- Inspect jacks for broken teeth or faulty holding fixlines and remove from service if there are any signs of hydraulic flid leakage, malefactions or other defacts. Test jacks under load conditions after repaire have been made.

Important points in maintenance of MHE:

- Training is the key to safe material handling and the operation of equipment being used to complete the job.

- Training will help to reduce unnecessary damage to equipment and prevent personal injury to employes.

- Selecting the right equipment for the jobs is also important task.

- For example selection of proper fork lifts for work inside a closed warehouse.

- The obrious choice would be an electric fall lift to avoid carton monoside explore from the exhast.

- Another example is selecting a hand truck for rough ground or floor conditions.

- In this case with rough ground or floor conditiona hand trucks with lager preumatic wheels would be the right choice.

- There is no single, complete maintenance program which will fit all your needs.

System approach to maintenance:

- The proper operation of on industry requires appropriate strategies in maintanence management.

- This is ensured by the effective integration of various phases involved in management.

- A good maintenance management can be considered as having six phases as shown in fig 5.1 they are

    - Planning

    - Scheduling

    - Execution

    - Reworking and

    - Analysis

Work identification is done by this methods.

L-5 six phases of good maintenance management

Work identification

Work planning

Work scheduling

Work execution

History recording

Analysis

For proper identification and communication of these six phases, system approach to maintenance was developed. The important steps in this system approach are

- Codification and cataloguing
- Preparation of history sheet
- Preparation of instruction & operating manual
- Preparation of maintenance manual
- Maintenance operation liaison
- Maintenance work order permits system.

Computerized maintenance management system (CMMs)

- There is a need to integrate the decision support tools in maintenance function. Support tools in maintenance planning and execution for the efficient discharge of the maintenance function.
- There is an increasing trend in application of information based decision support systems in different departments of modern

industry.

- Thus computers have become an indispensable requirement in maintenance management

- Computer is an efficient and reliable tool for maintenance personal to plan and implement their programmers.

- The success of CMMS depends on the quality of integration of computer system in maintenance management.

- Computerized maintenance management system (CMMS) is used to track all maintenance costs and equipment repairs.

- This tracking is accomplished by the monitoring of work orders.

- This task will provide necessary information to track and plan and maintenance budgets.

Effective cost control through CMMS is also achieved by the monitoring of purchase and inventory costs. This will track spare part costs and aims to avoid excessive inventories.

This module also helps in vendor selection and monitor the shipping time.

A computerized maintenance management system includes the following aspects:

- Development of a database

- Analysis of available part records

- Development of maintenance schedules
- Availability of maintenance arterials
- Feedback control system
- PEM
- Project management.

COMPUTERIZATION OF MAINTENANCE SYSTEM

Computerization of a maintenance work order system enhances and improves maintenance efficiency if the correct computer system for the installation is used.

The computer maintenance system is more effective if there is a manual work order system already in fork.

The objective of computerized maintenance system is as follows:

- Maintenance of existing equipment
- Inspection and service of the equipment
- Installation or revamping of the equipment
- Maintenance sharkeeping
- Craft administration

L6-Advantages of computerized maintenance management system

The features in the computerized maintenance management system provide the following advantages to the user:

- Improve maintenance efficiency
- Reduce maintenance asks
- Reduce the equipment downtime by proper scheduling
- Reduce the overtime and ensure optimal utilization of man power
- Increase the lift of equipment
- Provide historical database to assist in maintenance planning and budgeting
- Provide maintenance reports in specific formats depending on the requirements.
- Quicker access the plant maintenance statistic
- Conformity with health and safety standards

The overall reduction of maintenance costs after the introduction of a computerized maintenance management system in the diagram given fellow

Work identification

Work planning

Work scheduling

Work execution

History recording

Analysis

General structure of computerized maintenance management system

Most computerized maintenance management systems accomplish this objective through the use of four system modules. They are:

- Work order planning and scheduling
- Maintenance store contracts
- Preventive maintenance
- Maintenance reports

Work order planning and scheduling:

Computerized work order are documents that detail maintenance works. The computerized work orders should contain information such as

- Work order
- Details of equipment for which work is requested

- Description of work

- Type of work such as emergency routine, preventive maintenance etc.

- The basis for an effective work order system is the work order number.

- All material and labour works are charged to this number

- Work order must be input into CMMS from a maintenance request from, which is filled is by the industrials requesting the maintenance work once the work order is in the system, the user may work at the work order, update it as it is being worked on, and remove it from the backlog once it has bear completed.

  In case of emergencies action being with mental instructions and the paper work follows later, the plant uses the work order form as the document to record information associated with executing the work request.

L7-work order entry

The general work order entry requires the following information to be filled by the user:

- Equipment number that requires maintenance

- Priority and description of the work

- Estimated cost of work

- Information for dependent or associated work tasks for a complex maintenance jot.

Work order backlog:

The backlog is the storage area for all active work order

Work order system:

The work order system is the information system for the maintenance organization it is an important for an organization to maintain proper records to perform any meaningful analysis on its politicizes and procedures.

The computerized maintenance management system allows computer tracking and analysis of work orders as well as plant equipment data.

General structure of maintenance work order

Maintenance work order:

A Maintenance work order generally gires the following information

- Work order number and code

- Departments address and code.

- Date of issues.

- Detects of approval
- Date of receipt of work order
- Priority
- Location
- Equipment details

Planning and scheduling work orders:

It has four objectives:

- provide on efficient methods of requesting and assigning work performed by maintenance personal
- provide an efficient methods of transmitting written instruction on the work to be carried out
- to provide a method of estimating and then recording actual maintenance costs and
- to provide a method of gathering the information necessary to prepare reports for management

crafts:

the correct number of craftsmen may be scheduled so that work order is carried out in the most efficient manner.

Materials:

The material module should provide the following information:

- stock number of required parts
- quantity required
- cost per item
- description of item

tools:

CMMS require the following information about the tool:

- tool ID
- description of tool
- quantity required
- cost of tool(if necessary)

Scheduling:

It contains the list of work order its be performed. Scheduling module of CMMS contains the following information

- weekly schedules
- work order completion

- work order cost charges
- labor records

L8-Maintenance store controls

The two primary objective of the store control modules are to

- monitor material states
- monitor material resources

CMMS maintenance store module contains the following information to satisfy its objective:

- store stock material issue states
- list of unplanned materials
- planned materials
- stocks return
- stock item work order reference
- store catalog- stock number
- store cycle counts
- purchase order inquiry

- purchase order update

Preventive maintenance modules:

This function is used to change or update preventive maintenance scheduling information.

The preventive maintenance module of CMMS contains the following information

- user defined specific tasks
- grouping of tasks by crafts
- equipment preventive maintenance entry/update
- preventive maintenance meta recording update
- predictive maintenance

Maintenance reports:

The maintenance reporting function with provide management with the information necessary to operate the maintenance organization at peak efficiency

This report contains the following information

- work order priority analysis
- planner efficiency

- supervisor work order performance
- Still work order performance
- Work order costs report
- Completed work performance this field contain the information about total labour costs, cumulative costs and labour hours by craft
- Work order backlog summary
- Equipment repair history
- Equipment maintenance costs report
- Safety work order backlog
- Stock item usage report
- Work order waiting list
- Preventive maintenance overdue report

JOB CARDS AND JOB CARD PROCEDURES:

Job cards contain necessary detail necessary details for performing indiridual job in maintenance. Job card may be in the form of a card, sheet or paint out

Job card contain the following information:

- equipment code and shop code
- job code
- nature of job & job details
- initiation time
- job start and completion time
- man hours spent
- constraints/duriation

benefits of job card system

the following are the benefits and advantages of job card system

- information about maintenance history
- knowledge of frequency of maintenance for equipments
- details of equipment which require maintenance resources
- help in job auditing

- evaluation of costs of maintenance
- information about equipment downtime
- estimation of loss of production
- idea about man power utilization

L9-equipment records

They are information containing the details of installation service repair, maintenance activities, conditions, defects, schedules and plans for future implementation equipment records are to be used to maintain control on maintenance cost, reliability and availability

Types of equipment records

They are many types of equipment records available in industry catering to various needs. They are as follows:

- planned work and percentage to planned work achieved
- ratio of planned to planned work
- production delays & downtime
- ratio of preventive work to corrective work
- failure patterns
- repetitive breakdown

- manuals including operating manual, instruction manual, maintenance manual, job manual and drawings
- history cards and records
- spall cards
- maintenance requirement records
- performance details
- cost reports
- condition monitoring reports

Advantages of equipment records:

The following are the advantages of equipment records:

- clear picture about the details of maintenance programmers is obtained
- Information about completed, pending and regular jobs carried out to the equipment are available.
- Records discriminated to various units of the industry helps in standardization of procedure.
- Evaluation of performance of maintenance

tasks

- Provide detads of frequency of maintenance requirements for each equipment

- Comparison of time taken for completing the maintenance job with parts records

Maintenance work execution, monitoring and control

A well designed organization should have proper strategies to execute, monitor and control over the various maintenance tasks

Monitoring:

The role of monitoring in maintenance has the following advantages:

- Gather information about derivation and delay in execution of maintenance may provide idea about the need to add more resources to complete the maintenance tasks in scheduled time frames

- Communication of the changes in jobs content to the various follow up agencies.

- Provide information about constraints in technical issues and necessary steps can be taken to improve the existing techniques

- Provide a lead to implement technical advancement and methodologies in future to complete the tasks in more efficient manner.

Control:

The system shows the interaction between shop supervisors and maintenance executes. After the constraints of material or resources met, unfinished maintenance tasks will be executed.