Module_5

Maintenance Management

Géza CS. NAGY

Maintenance and organisation

Module_5

Maintenance Management

Géza CS. NAGY

Maintenance and organisation

TABLE OF CONTENTS

1. THE SYSTEM OF MAINTENANCE ACTIVITIES

1.1. CONCEPTUAL FRAMEWORK OF MAINTENANCE

Today's understanding of the concept of maintenance, from the point of view of business efficiency, takes into account all factors from construction to scrapping that affect the availability of machinery and equipment. The words 'maintenance', 'repair' and 'overhaul' do not sufficiently express this endeavour. This is why several terms have appeared in technical literature, such as complex or integrated maintenance, comprehensive preventive maintenance, terotechnology.

In essence, terotechnology is a cyclical process involving the design, manufacture, installation, operation, maintenance and continuous preservation of machinery and equipment, as well as the ongoing administration and management of machinery and equipment.

In practice, the concept of a complex maintenance system corresponds to the concept of terotechnology. This is the basis for the management and

- the management of fixed assets (capitalisation-operation-decommissioning)

- maintenance, maintenance management

- level maintenance (fixed asset replacement) (see Figure 1.1).

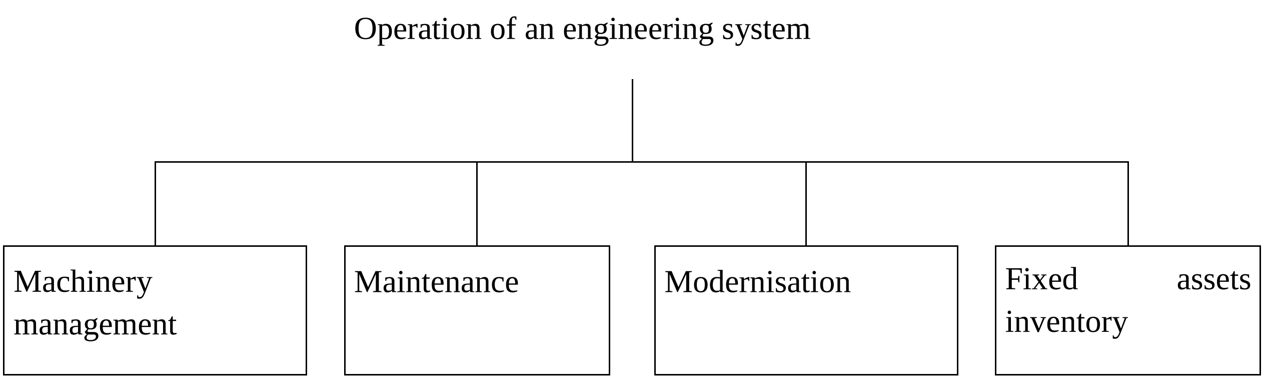


Figure 1.1. Areas of maintenance

Based on the previous discussion, it can be concluded that in the operational use of fixed assets, management and maintenance activities are carried out in parallel and in close interrelation.

1.1.1 THE CONCEPT AND FUNCTION OF MAINTENANCE

Industrial enterprises aim to achieve long-term profitability by using their inputs and labour to transform relatively low-value inputs into valuable products. Achieving this goal requires a wide range of activities, such as marketing, sales, design, production and maintenance of inputs, and the building, machinery, equipment and various tools to produce the space. The production process therefore starts with the installation, followed by the operation of the fixed assets purchased. During use, maintenance must be carried out in order to ensure that the equipment is in good working order, while various repairs are also necessary. Machinery, vehicles, etc. which are worn out and no longer meet the technical requirements must be scrapped and replaced by new ones when necessary. New purchases, in other words replacements, can be either level-maintaining or production- or productivity-increasing.

Maintenance of machinery is the technical activity of ensuring the constant and orderly use of fixed assets in a plant (factory, enterprise), and of carrying out the related organisational, maintenance, training, record-keeping and administration tasks,

install new equipment, scrap obsolete equipment and provide advice on the purchase of new equipment.

Maintenance resources must be used to ensure that the machines can be operated in accordance with safety standards over their designed lifetime so that production targets can be achieved with optimum use of raw materials and energy.

The maintenance strategy, on the other hand, is to determine the maintenance metrics in the optimal use of resources in such a way that production and maintenance expenditure are in balance. The possible variations range from 100% preventive maintenance to 100% exclusive breakdown maintenance. The challenge is to choose the best ratio.

Maintenance also includes tasks that apply to both the producers and users of machinery, equipment and tools, since production involves the activities of both. In order to ensure that production is carried out in the desired manner, i.e. that the required quality can be maintained while the equipment is in a high state of working order, the necessary measures must be taken both technologically and in terms of plant maintenance.

At the same time, the evolution of maintenance must follow the evolution of production processes. If there is a significant gap between production and maintenance, the expected results of scientific and technical progress will not be achieved.

1.1.2. THE CONCEPT AND TASK OF MAINTENANCE

The objects of maintenance are the various installations, buildings, machines, fibre equipment, i.e. various material assets. For the sake of a uniform interpretation, maintenance and the operations of maintenance of fixed assets can be summarised as follows: - maintenance is understood to be the maintenance activity comprising all the operations which must be carried out in order to ensure the serviceability and proper use of fixed assets. [1]

Maintenance includes all the activities, according to the current situation of the unit under inspection (e.g. production or repair), by means of which the required condition can be maintained or restored and by means of which the actual condition can be determined, assessed or qualified.

The maintenance of the original utility value can be defined as the implementation of measures to keep wear and tear below the permitted level. This includes care, maintenance, cleaning, lubrication, drainage, aeration, preheating and compliance with the prescribed operating procedures.

Restoration to original service life is understood to mean actual maintenance, preventive maintenance, replacement and troubleshooting. Increasing the original service life means the installation of more modern machinery and equipment as part of the general repair.

For organisational reasons, the system can be divided into continuous tasks (cleaning, cleaning, maintenance, etc.) and intermittent tasks (all repair operations). In practice, both continuous and intermittent tasks have developed into a well-established system, and there are several ways of combining them. It is clear that, if well organised, continuous maintenance operations (e.g. lubrication) will cause little or no disruption to production, while repairs will almost always interrupt the operation of a plant.

The DIN definition of maintenance is as follows: "Maintenance is the sum of measures taken to preserve, restore and maintain the desired condition of a plant in its current condition.

to establish and assess the following. These activities: review (inspection, inspection), maintenance (treatment), repair (repair), include the alignment of maintenance objectives with the business objectives and the definition of an appropriate maintenance strategy."

The grouping of maintenance measures is illustrated in Figure 1.2.

Maintenance

task

the technical means of the system

maintaining the required condition	establishing and assessing the actual condition	restoring (repairing) the required condition
Operation and maintenance	Supervision and inspection	Repair and maintenance

-Proper use	– control inspections	– various types of repairs
- cleaning	– measurements	– replacements
- adjustment,		
- lubrication	– inspection	– renovation
- preservation		

Figure 1.2. Parts of maintenance (general maintenance measures)

However, even before the most conscientious technical diagnostics and maintenance, it can (and often does) happen that the actual values of the various technical indicators fall below the permissible values, i.e. the machines fail. In the great majority of cases, it is then necessary to adjust the technical characteristics which have fallen below the failure limit to the factory or other acceptable values, i.e. to repair the machines which have failed, often by taking them out of production, and to ensure the continuity of the work, to replace the machine which has been taken out for repair by another machine. There are two main ways of repairing: new (manufactured) and reconditioned parts. Replacement repairs are very common. New spare parts are sometimes produced by the repairers themselves. In practice, it is often the case that machinery is repaired with reconditioned parts for reasons of realistic technical and economic considerations. The technologies used to refurbish the parts are generally the same as those used in production, or at least a fraction of them. However, in recent decades, the repair industry has independently developed processes that are ideally suited to the restoration of degraded technical condition of machinery parts. Thus, a very wide range of reconditioning technologies has emerged, such as machining methods, plastic forming, welding, soldering, casting, metal spraying, powder metallurgy, galvanising, chemical coating, plastic bonding, adhesives, surface alloying, surface silicon finishing and heat treatment.

However, even before the most conscientious technical diagnostics and maintenance, it can (and often does) happen that the actual values of the various technical indicators fall below the permissible values, i.e. the machines fail. In the great majority of cases, it is then necessary to adjust the technical characteristics which have fallen below the failure limit to the factory or other acceptable values, i.e. to repair the machines which have failed, often by taking them out of production, and to ensure the continuity of the work, to replace the machine which has been taken out for repair by another machine. There are essentially two ways of repairing: new (manufactured) and reconditioned machine parts. Replacement repairs are very common. New spare parts are sometimes produced by the repairers themselves. In practice, it is often the case that machinery is repaired with reconditioned parts for reasons of realistic technical and economic considerations. The technologies used to refurbish the parts are generally the same as those used in production, or at least a fraction of them. However, in recent decades, the repair industry has independently developed processes that are ideally suited to the restoration of degraded technical condition of machinery parts. Thus, a very wide range of reconditioning technologies has emerged, such as machining methods, plastic forming, welding, soldering, casting, metal spraying, powder metallurgy, galvanising, chemical coating, plastic bonding, adhesives, surface alloying, surface silicon finishing and heat treatment.

Sooner or later, as a result of the physical, chemical, biological and human-induced deterioration processes that occur during operation, as well as the technical-economic (ideological) obsolescence that occurs from the moment of intellectual birth, the point comes when the further maintenance of machines and equipment is no longer required by companies (they no longer consider their operation economical) or cannot be required (because the machines are damaged in some way: crash, fire, etc. This moment, i.e. the date of decommissioning, is considered to be the final decommissioning or cessation of the machinery and equipment.

A good example is the failure of the starter of a truck engine, at which point it must be decided whether the operator should wait for it to be repaired or whether a good starter (new or reconditioned) should be installed. The decision must be weighed against the difference between the cost of a longer but less time-consuming repair and the cost of a longer but more time-consuming replacement of the starter, and the loss of downtime. If the transport task planned with a given truck is not urgent, and thus no delay fee is payable for the delay in the waiting time, it is almost natural that the cheaper repair is the preferred option. However, if the goods to be delivered have to be delivered on time, because of the considerable hourly delay charge, it may be economical to replace the starter.

Each step in the process of maintaining a machine therefore has its own technical and economic importance. It also has a special role which goes beyond the boundaries of the various systems and disciplines and has a direct impact on machine design and manufacture. In fact, during the maintenance of machines, as a "third stage", the various technical pseudo-characteristics which determine the maintenance of the machine must be reassessed, as a result of the regeneration and "renewal" of the various technical pseudo-characteristics which determine the maintenance of the machine, inevitably and inevitably, the construction and operation plans must be revised. Successful completion of this work will, of course, open up further opportunities to raise the technical standard of the plant, reduce costs and modernise the existing production facilities.

On the other hand, in the case of reconstruction, the design and technological errors made lead to a sharp increase in operating costs and a rapid deterioration in the performance of the machines.

It is instructive to reflect on the change in the financial indicators for the signal-collection nodes of the main process from the machine's birth to its scrapping, as illustrated in Figure 1.5. It can be seen from the figure how the successive cam¬ue events in the chronological order affect the product's expenditure. The two curves illustrate the extent to which each of these activities is associated with a range of expenditure-saving opportunities, and hence variation costs. In the decision preparation and decision making process, extremely high margins can be achieved at low switching costs.

The costs of change in successive activities are increasing, while the opportunities for cost savings are increasing. Switching costs are highest for the maintenance activities required during the maintenance period. This also illustrates why, in the case of heavy farming, the scrapping rather than the repair of morally or technically obsolete machinery is the reason for the divisions' decision to scrap rather than repair. This also implies that the quality and reliability of the machine is most important at the market, pre-design and pre-decision, design, assembly and manufacturing stages of the life cycle (i.e. the stages that determine the quality and reliability of the machine), as it is at the subsequent stages of the life cycle (operation, maintenance, repair, maintenance, repair, maintenance, etc.) that quality and reliability are most important, maintenance), the only realistic option is to preserve the quality and reliability of the machine purchased and to minimise its deterioration. At this stage in the life cycle of the machine In practice, as experience has shown, the best way to maintain quality is to follow professional cultivation standards.

However, it is also a fact that, even in the case of professional machine operation and maintenance, the machine must be scrapped after a certain number of hours of operation.[2]

When a machine is finally scrapped, there are three broad categories of parts:

- Re-use: these are the parts that can be rebuilt to their original condition without modification, reused in some form in another area, either as refurbished parts, or rebuilt as new parts in their original location, or used to create a completely different, new product using some technology.

- Destruction: parts or other waste that cannot be recycled (e.g. used oil, plastic parts, textiles, etc.) are incinerated in accordance with environmental standards.

- Long-term storage: hazardous wastes whose destruction is not technically feasible or economically viable must be stored in accordance with very strict environmental standards.

We should also mention trade and after-care as key activities.

Companies sell their finished products in various forms:

- The most common way is through commercial enterprises.

- Less common, but also common, is that companies are in contact with customers indirectly.

The three main activities of product aftercare are usually as follows:

- Warranty service: the manufacturing company takes care of failures within a certain period of time, free of charge, through an appropriate repair and service network;

- Spare parts supply: the company is obliged to provide spare parts for the products it sells for a limited period of time, which may be provided by the manufacturing company itself, but in most cases by the customer or the repair or service network;

- maintenance: the repair of faulty machines can rarely be carried out by the manufacturing company, but most often by repair and service companies, and to a lesser extent by the operators themselves, with the help of specialised repair and maintenance technicians.

1.2. PURPOSE AND NEED FOR MAINTENANCE

The repair (maintenance and servicing) of machinery and equipment coincides with the emergence of the machinery industry, but the content and importance of the activity has always been highly dependent on time and space. [2]

The perception of this issue has differed and continues to differ both between countries and within countries. Attitudes and behaviour on the part of the country or group (person) are also influenced by the material situation.

It is clear that repair has become a more important factor, especially where the scarcity of resources has not allowed frequent replacement of assets. It can be said that this issue reflects different maintenance philosophies, and that the maintenance of machinery is taking on less of its rightful place, both in industry and in science. The development of technology, the production process and the The safety of machinery is increasingly demanding highly skilled maintenance professionals. Troubleshooting repairs are increasingly being replaced by planned machine maintenance based on technical diagnostics, which can be the basis for the practical elimination of machine breakdowns caused by unexpected faults.

The aim of machine maintenance is to ensure that a machine (equipment, apparatus, building, etc.) is in good working order by implementing various corrective measures. These measures should be scheduled so as not to hinder the continuity of production. Any machine downtime will lead to an increase in production costs. The so-called idle periods, when the machine would otherwise not be working, can be used to great advantage for machine maintenance. This could be, for example, a shift when the machines are not working. And for seasonal machines, it is natural to use the days of the calendar year when no maintenance task is programmed for the machine.

The need to maintain the machines: the need to maintain the machines can be justified primarily by the need to maintain a smooth running process. This can be explained by the fact that the strength characteristics of structural materials and the service life of components not subject to such stress do not yet allow the design of equipment with a uniform service life, so that a component or sub-assembly may need to be repaired or replaced one or more times during the life of a machine.

The objectives to be achieved through maintenance:

- Maximise the productivity of the production/service equipment

- Prevent unexpected breakdowns

- Minimize production losses

- Increase the technical reliability of the assets

- Maximize equipment lifetime

- Improve product/service quality and, through this, customer satisfaction

To summarise, it can be concluded that machine maintenance, its planning and its frequent implementation (e.g. planning methods that determine repair technologies and maintenance times and durations) can influence machine operation for better or for worse. The review of design and operation plans during machine maintenance naturally affects all the components that are relevant from a maintenance point of view, but they are mainly related to the working parts and tools of the machines. The values of certain technical condition indicators relating to the operation of the machinery change during the repair phase, and are usually improved.

The activities of the production plant are decisive in ensuring that the technical condition characteristics of the machines reach the level required by the operator. It is very encouraging that machinery manufacturers are investing considerable sums in research, design, the introduction of more advanced production technologies, and modern factory production facilities, in order to improve the quality of their products and certain of their characteristics. More worryingly, the 'third birth' of their products is generally given much less attention. This would make the work of machine repairers much easier. At the design stage, more attention should be paid to the frequency with which parts and sub-assemblies fail during the life of the machine and the number of times it has to be dismantled for repair. The ability to repair failed parts quickly also depends on whether the design ensures that the favourable accessibility from the point of view of fitting the sub-assemblies. At the same time, for components that require a lot of lead time, it would be desirable to use materials and technology that ensure a sufficiently long service life.

At present, machine repair specialists have to solve very complex problems, requiring a wide range of theoretical and practical skills. In order to be effective in the review of machinery maintenance plans, he must be familiar with the objectives set in the original plans and the methods by which new objectives can be achieved. The complexity of the issue is further increased by the heterogeneity of organisational forms.

In terms of organisational forms, maintenance may be directly linked to the production company or to a manufacturing company, or it may be a completely separate business with its own operational activities.

There is also a growing environmental need to produce equipment that minimises the amount of subcomponents and other auxiliary materials that have to be disposed of or stored for the long term.

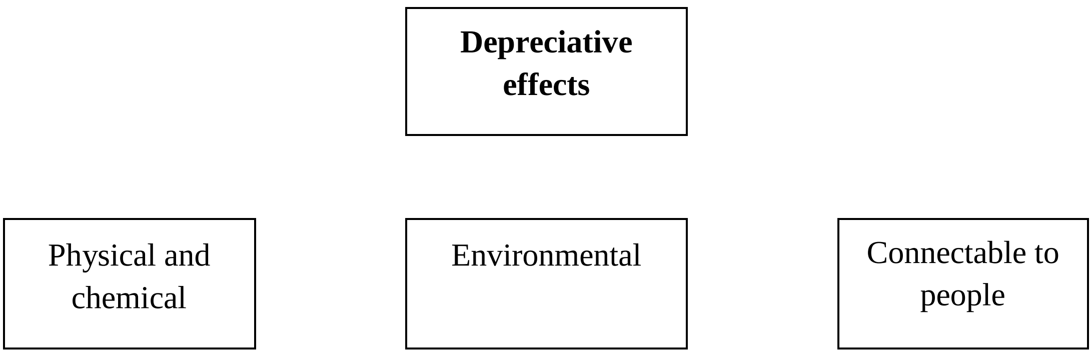
Of course, there are many items that are not economical to repair. For example, no-one would want to repair a faulty light bulb, as the technology of repair would be very complicated and expensive. We prefer to replace many difficult-to-access faulty parts that require repair, even if it is cheap to repair, because the loss of production time that can result from more frequent breakdowns can be very damaging. At the same time, it goes without saying that a car will not be scrapped because of a blow-out or a large valve gap, since the cost of repairing the defects is significantly lower than buying a new car.

The fundamental problem is not usually whether or not it is cost-effective to repair certain faults, but rather how economical is it to keep an expensive machine (e.g. an au¬tor, locomotive, tractor, combine harvester) with many components in operation? When is it optimal to scrap a machine and replace it with a new one?

2. DETERIORATION PROCESSES IN EQUIPMENT AND WORK TOOLS

During their operation, equipment and technical tools are subject to constant stresses which reduce their utility value and thus cause them to lose their serviceability. These effects vary in their nature, form, cause and time course.

In terms of the nature of the influences, a distinction can be made between physical, chemical, biological and human-related effects (Figure 2.1). Wear and tear due to technical stresses can cause damage such as changes in size or shape, changes in the geometric relationship between parts, changes in the quality of surfaces or other factors. These cannot be avoided even when using the work tools with care.



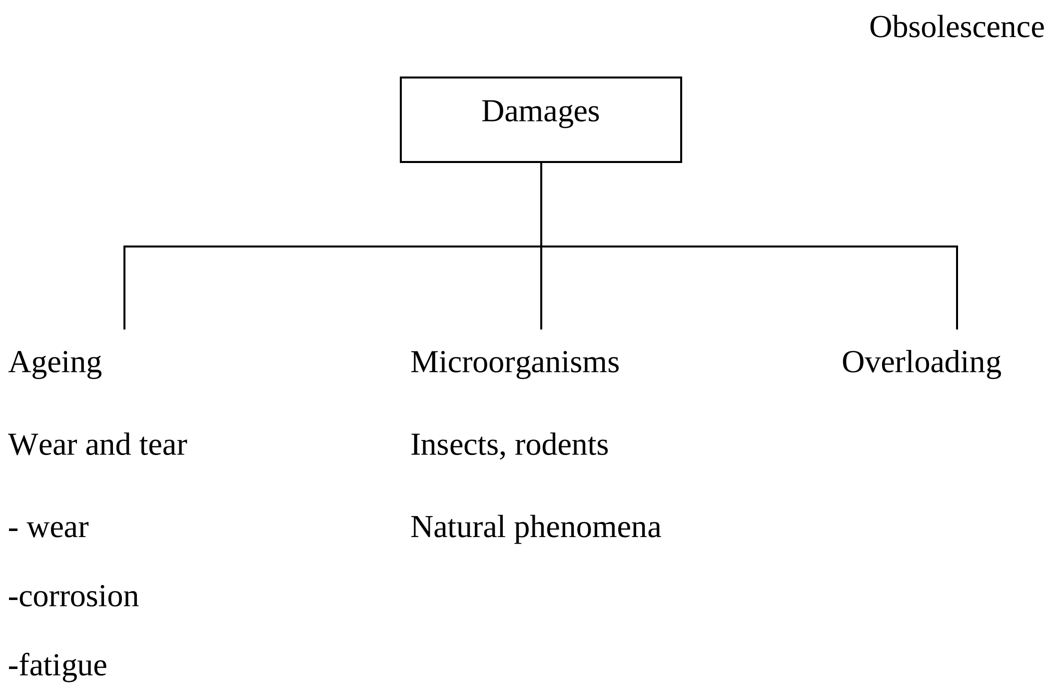


Figure 2.1. Depreciation effects on technical equipment

Ageing is only considered as a harmful effect if it occurs outside the manufacturing process. Ageing is a process inside a material that results in a permanent loss of strength or other properties, depending mainly on the age or the environment of the tool.

The techno-economic effects linked to people cause a depreciation of the working tools. This is the result of the fact that technological progress makes it possible to produce new, more productive, better quality, more efficient work tools. In this case, we are talking about the ageing or moral obsolescence - wear and tear - of work tools.

The cause of overloading is to be found in the incorrect handling and deterioration of technical work equipment. This can cause direct damage. It can also cause damage indirectly, or misuse can accelerate wear and tear.

2.1. TYPICAL DETERIORATION PROCESSES

They occur during the process of painting. The great majority of them are therefore characterised by a significant change in the post-production period, i.e. during the period of sale and then operation of the machinery. For example, the condition variables tend to improve during commissioning, adjustment, machine repair and overhaul, and deteriorate during the period of machine operation and storage. They are characterised by the fact that they a limit value can be assigned to each of them, after which the machinery part or machine in question is deemed to be defective.

The deterioration of the technical condition of machinery is caused by various processes. Among these, the most important from the point of view of machine maintenance are described in detail:

- friction and wear,

- cracking and fracture,

- corrosion.

2.1.1 FRICTION AND WEAR

Wear and tear is the most common deterioration process in mechanical engineering and is usually the result of friction. During wear, the surfaces of components that are friction-stressed against each other or against foreign material (working fluid) suffer a reduction in size and mass.

The phenomenon of wear is understood to be the detrimental separation of small particles of material with macro- or micro-structure from the friction surface. By definition, wear does not occur when two materials come into contact and one transfers electrons to the other.

Friction can be defined, in general terms, as an impediment to motion. In a narrower sense, friction is the set of phenomena that occur when surfaces in contact with each other move relative to each other and act prior to movement.

There is currently no clear link between friction and wear. Friction can be achieved with negligible wear, but wear without friction is inconceivable. This explains why the exploration of the relationship between the two phenomena has become a fundamental subject of research in a new discipline, tribology (friction-wear science).

Research into tribological processes has shown that well-designed machines can only be developed and operated reliably if friction and wear are treated as characteristics of a tribological system. Due to the complexity of tribological systems, it is of particular interest that scientifically sound and practically usable relationships can be established by applying general systems theory and the method of technical systems analysis.

The loss of material due to friction, which is the result of mechanical, thermal and chemical stresses during the friction process, can be expressed as follows:

- mass transfer from one element to another,

- particles of material are detached and released into the surrounding medium,

- chemical reaction products are formed.

Wear, termed mild depending on the amount of material loss, is the shedding of the top surface layer, where the surface remains relatively smooth, the structure retains its functional capability over a long period of time, and thin, disc-shaped, highly oxidised wear particles are formed. In severe abrasion, internal parts of the material are torn away, the surface becomes rough, the functionality of the structure is impaired or even eliminated, and large abrasive particles, mainly containing base material, are formed.

Wear in the tribological system must be taken into account when characterising the wear:

- the mode of motion (sliding, rolling, impact, flow, vibration),

- the interacting elements,

- the prevailing wear process (surface fatigue, abrasion, adhesion, chemical).

To characterise the amount of wear, additional quantities should be taken into account, e.g:

- the energy input: normal force, friction coefficient, friction path length,

- the material properties that influence wear,

- the wear rate,

- the condition of the worn surfaces.

The processes causing wear on friction surfaces form characteristic lesions, surface patterns, which help to recognise and identify the prevailing wear process. The following wear patterns are usually distinguished:

- adhesion wear. During friction, atomic-molecular bonds formed at the roughness peaks are broken and material particles are transferred from one surface to another because the strength of the surface layer of the contacting surfaces increases relative to the internal material particles due to frictional stress and physico-chemical effects, and the tear (shear) occurs inside the material with lower strength. It can lead to extremely severe surface damage and chipping.

The adhesion hairs (similar crystal structure) of the two frictional surfaces play an important role in adhesive wear, as does the chemical reactivity and oxidation tendency of the parent material. In order to reduce the adhesion tendency, it is advisable to couple materials with significantly different crystal structures and/or heterogeneous fabric structures (e.g. cast iron with steel, bronze or other bearing metals, plastics with low adhesion tendency (PTFE, HDPE), plastic or metal composites, ceramics) or coatings (e.g. TiN, TiC, BN, PTFE, MoS2, Al2O3, Zr02, occasionally noble metals).

Oxidation and other chemical effects make repeated material transfer more difficult and cause stress concentration, promoting the detachment of the wear particle.

- Abrasive wear. During friction, a roughness peak or hard contaminant grain that penetrates the surface pulls a groove, while some or all of the material that emerges from the groove is detached as an abrasion particle.

The rate of abrasion is largely dependent on the hardness and the elastic modulus of the material exposed to the abrasive action, the hardness of the indenting tip (if it is at least one and a half times harder than the abraded material) having no significant effect on the rate of abrasion. For plastics, the wear resistance is more proportional to the elongation at break.

The service life of the structure can be increased by effective sealing to protect friction surfaces from contamination, by optimally smoothing hard friction surfaces, by using high strength but tough materials or by hard but not brittle surface coatings.

- fatigue wear. Caused by repetitive stresses during sliding or rolling. It is also influenced by: stress accumulation effects inside the material (oxide and other hard inclusions, grain boundaries, dislocations), surface characteristics, defects (roughness, residual stresses, corrosion holes, impurities), unevenness of load distribution (elastic deformation, uniaxiality defect, gap adjustment).

In the case of bodies rolling on each other, cracking starts at the stress accumulation sites inside the material (at locks, crystallite boundaries, lattice defects) and leads to crater-like cracking and pitting as it progresses towards the surface. In sliding, the tangential stresses cause cracking parallel to the surface, and only after a certain length is reached does the crack turn towards the surface and lead to the formation of a plate-shaped wear particle.

- mechano-chemical wear. It occurs mainly when metals frictionally wear, and is largely caused by the dynamic (chemical and mechanical) friction between the friction bodies and the medium (oxygen) that enters between them. interaction between. During the frictional process, the surface layer of the material is transformed by the stresses (plastic deformation, crystalline fragmentation, direction of movement), and a secondary - protective - fabric structure is formed. At the same time, the frictional stresses also load the protective surface layer, deforming it, creating stresses, cracks and cracks in the surface environment, which ultimately leads to the abrasion of the protective layer (activation energy).

If, under stress, the rate of wear of the protective layer exceeds the rate at which it is rebuilt, the protective effect is progressively lost, the substrate is damaged and severe surface damage (chipping, indentation, pitting, etc.) occurs, preventing the structure from functioning. In this case the wear particles are large and usually contain a lot of metal.

From a tribological point of view, it is desirable to have a durable, wear-resistant, thin surface layer on the friction surfaces - which wears slowly and gradually, while constantly reforming - in which the chemical reactivity of the lubricant (additive) plays a decisive role.

- cavitation wear. It can occur on surfaces of solid bodies in contact with flowing fluid, where unfavourable flow conditions cause gases dissolved in the fluid to precipitate in the form of low-pressure bubbles, which then collapse and cause severe fluid collisions on the surface of the solid body. The liquid collisions cause strong mechanical stress (the resulting pressure can reach 1500 bar), causing cracks to propagate from the surface to the interior of the material and create hole-like craters.

Only materials with a homogeneous structure, high strength but at the same time tough can withstand intense cavitation to a certain extent. Manganese steel with austenitic structure is the best.

- fretting wear or fretting corrosion. It occurs when surfaces in contact with each other vibrate at low amplitude (70-700m) relative to each other, creating alternating friction in the contact zone. This process can cause localised abrasion, surface pitting and incipient fatigue cracking at the contact surface, which drastically reduces the fatigue limit of the materials.

To avoid this, modification of the structure is the best solution, but the process can be slowed down by blocking the ingress of vapour or oxygen (sealing, painting).

- erosion wear. It occurs during the transport of solid particles (sludges, dusty gases), bulk materials (cement, granular products) in pipelines (mainly in bends causing flow reversal), on surge tanks, in transport equipment, in electrical machinery.

The kinetic energy of particles hitting a solid body is transformed into impact energy (the wall and the particle deform elastically and/or ductile, brittle fracture), the impacting particle tears material fragments from the wall. The amount of wear depends on the parameters determining the kinetic energy (direction and speed of impact, mass of the particle) and the properties of the material subjected to the wear and the particle impacting (solidity, hardness, deformation capacity, particle size and shape, etc.).

It is often possible to reduce erosive wear by modifying the structural design, or by placing abrasion-resistant inserts in heavily used areas, or even by allowing the flow to cause solid particles to be deposited on the wall in the exposed sections and protect it from abrasive stress.

The latter two are not the result of a single process, but of the simultaneous or successive occurrence of several processes. 2.2.2. Cracks, fractures

Cracking is the most damaging defect because it most often causes fracture. Cracks are generally caused by stress concentration zones (notches, holes, wedge grooves, material defects, inclusions, corrosion). Cracking can thus be understood as a resultant failure, a precondition for fracture and a transition between material defects, continuity failures and fracture.

The development of cracks into actual fractures is the result of a combination of factors. The combined dynamic regime of the mechanical design, the nature and size of the material continuity deficiency, and the stress resulting from the loading determines whether or not fracture will occur and, if so, what type of fracture.

Basically, two types of fracture can be distinguished:

- fracture of the rib and

- fatigue fracture.

The cracking of a material is caused by stresses, and the crack initiation is preceded by elastic and then residual deformation. Several hypotheses have been put forward for crack initiation, two of which seem to be confirmed:

- the slip theory states that if the local stress in the material exceeds the yield stress, the crystallites will slide on each other and a micro-crack will form in the direction of the slip and

- according to dislocation theory, lattice defects are stress accumulation sites and, as continuity defects, are the cause and origin of cracking.

The propagation velocity of the crack determines whether it is a fatigue crack or a fracture. A rapid splitting of the entire load-bearing cross-section of a metal structure, accompanied by a sound phenomenon, is called a fracture.

The conditions for the propagation of a crack are described by Griffith in terms of energy relations. Rupture starts to propagate in the material when the stress intensity factor (Ki) reaches a certain value. The stress state around the crack tip causes the crack surfaces to move perpendicular to the plane of the crack.

The phenomenon of material fatigue due to repeated stresses was addressed by Wöhler. He found that the local crack starts at the weakest or most stressed point of the polycrystalline structure and either stops or propagates depending on the stress signal. The fatigue life is influenced by several factors (structural design, nature of the stress, surface roughness and environmental conditions).

Given that material defects play a significant role in fracture processes, in addition to operational stresses and environmental hazards, their typical forms and causes are briefly summarised.

The strength reducing effect of material defects is twofold:

- they reduce the load-bearing cross-section, or

- cause stress distortion.

The reduction in load-bearing cross-section is proportional to the size of the defect. If this is known, the reduction in strength can be accurately calculated. Stress distortion produces a heterogeneous stress distribution, the magnitude of the stress peak being influenced by the geometry of the component and the spatial location of the material defect. This will ease tensions. If the material is brittle or cracked, microcracks will form, which will propagate and cause fracture. The strain or stress-strain coefficient (k) is used to characterise the stress-strain reducing effect. Its value is one for a smooth specimen of homogeneous material without incision, and greater than one for other, less favourable, specimens.

Material defects (continuity, lattice, crystal deformation) may be due to technological, design and operational causes. Material defects are classified into the following groups:

- gas seals - usually spherical or with a rounded surface, therefore less dangerous from a stress-strain point of view. Gas seals are designed with a stress-strain factor of k~3.

- Slag traps - are non-metallic materials and are usually irregularly shaped, so they cause high voltage drift when acting as a sharp incision. Their stress-strain coefficient

k=4-5.

- Stratification - caused by corrosion, defective rolling or forging. Copper sharpness also acts as a sharp notch, can be very dangerous depending on direction and size; k=3-5.

Ageing is also related to defects in the lattice structure of the material. The lattice defects change their position under the influence of principal stresses caused by external forces. When they reach the crystallite boundary, the originally defined yield strength is blurred, resulting in an increase in hardness, a decrease in elongation and a decrease in specific impact work. A distinction is made between forming ageing, which can occur at as little as 10% cold working, and hardening ageing, which mainly occurs when mild steels are rapidly cooled from 700°C.

The change in texture is caused by the anisotropic property of the material. Higher degrees of deformation (e.g. 25-30% elongation) result in elongation of the crystallites, beyond a certain limit the micro-granules are distorted almost to the point of disintegration. Such a material becomes more solid in one direction, and the cracking or fracture occurs not at the grain boundary, which is usually more dense in the alloying elements, but in the crystallites. At such a fracture surface, the crystallites in the deformation zone are distorted and duller in luster.

2.1.2. CORROSION

Structural materials and semi-finished products undergo chemical transformation in the first stages of their manufacture. In the case of metals, for example, the non-ferrous metal enters a state of higher energy than the initial ore raw material, which is energy-intensive and, depending on environmental influences, can only be maintained for a limited period of time. According to the well-known law of entropy, the energy processes of material systems are such that, even without external intervention, they tend to reach the lowest, i.e. most stable, energy state. In practice, this is the classic formulation of age-rotation, which applies not only to metals, but also to almost all man-made materials, be¬ton, plastics, etc.

Corrosion is therefore a reaction of metals and other structural materials with the environment, whereby chemical or electrochemical processes cause the material to revert to a more stable, lower energy form.

For example, iron ore, in which the metal occurs in oxide or hydroxide compounds, can be reduced to pure metal by an energy-intensive reduction process. From this higher energy state, if the metal is not protected, it is converted back into oxide or hydroxide complex compounds, *depending on the environmental conditions. In copper ores, it is found in sulphide or basic sulphate compounds and is* converted back to sulphide or basic sulphate during corrosion.

Corrosion, as a process that causes a technical failure, causes dimensional and mass changes in the component, as well as a loss of strength. In an atmospheric environment, corrosion is always present in the wear process of metals. A disadvantage of corrosion is that it damages our machines not only during operation but also during storage, in all cases if we fail to protect against it. Mechanical equipment often works in corrosive media or with corrosive materials, and corrosion is the cause of many technical faults.

Corrosion can occur in liquid, gas and solid media. We can talk about them in terms of seawater:

- liquid corrosion,

- atmospheric or gas corrosion and

- soil corrosion.

We distinguish between the following according to the mechanism of the process:

- chemical

Interfacial reaction between a solid metal and a gaseous medium (e.g. oxygen), which has an ion-destroying effect on the metal. The reaction layer can be thin and its thickness depends on the time and temperature of the reaction, indicated by the so-called run colours. A typical example is the formation of rust.

and

- electrochemical corrosion.

Metals release ions into solution in the presence of electrolyte. For each metal, this difference in pressure varies in magnitude (depending on the normal po-tency defined in the electrochemical voltage series) and is known as the electrolytic solution pressure. Mechanism: charge exchange occurs in small areas of locally separated metal surfaces. A galvanic element is formed as a result of the voltage difference between these areas. The farther apart the two components of the local element are in the voltage series, the greater the corrosion of the less noble metal in question.

Both the chemical and electrochemical reactions create, or tend to create, a state of equilibrium. The initiation of corrosion depends on the thermodynamic equilibrium of the interacting materials. Once the process is initiated, an important issue is the rate of corrosion, which is influenced by a number of factors. To understand the mechanism of action of corrosion processes, the thermodynamic fundamentals of the subject and the laws of corrosion processes must be studied to reduce the corrosion rate and to protect the environment.

The different forms of corrosion can be distinguished according to the places where they occur (Figure 2.2). Surface corrosion is the uniform degradation of the metal at all points on the surface (for iron, about 0.2...0.4 mm/year). Surface corrosion is relatively harmless and can be easily detected and prevented.

Selective corrosion attacks alloys.

The

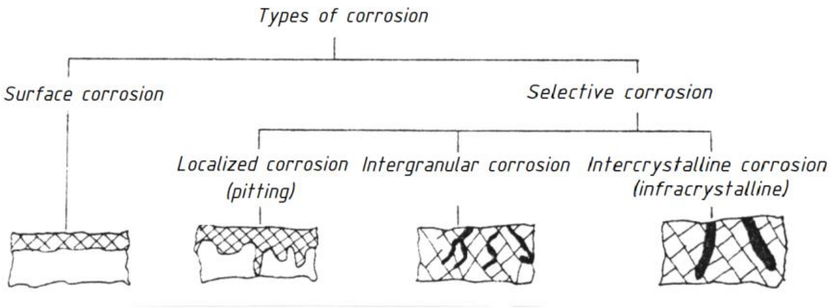


Figure 2.2. Forms of corrosion

concentration differences in the alloys are responsible for the local ron-deterioration of the material, which causes a reduction in strength due to the stress-absorption effect. The alloy can even perforate. It is much more severe than surface corrosion because it is difficult to clean up externally. Local corrosion is also known as pitting or pitting corrosion.

Intercrystalline corrosion is the deterioration of a material at the grain boundaries. The magnitude of this variant, called stress corrosion, depends on the position of the alloying constituents in the electrochemical stress series or the degree of impurity. It is also influenced by the particle size of the material. The coarser the grain size of a material, the smaller the sum of the grain surfaces, therefore the higher the concentration of contaminants at the grain boundaries and the greater the intergranular corrosion. The extent of intergranular corrosion depends on the structure (coarse or fine grain), the presence of impurities and the position of the alloy constituents in the stress series. It is particularly dangerous because it cannot be recognised from the outside. Another particular form of corrosion is pitting corrosion, which occurs on sheet metal components and causes the sheet metal to separate into layers.

Intracrystalline corrosion is similar to intercrystalline corrosion, but in this case the corrosion surface passes through the crystals. It is often caused by mechanical stress (stress corrosion cracking).

Some possible ways to protect against corrosion:

- Design a structure that allows inspection of the components to detect damage at an early stage, avoiding stress corrosion cracks, uneven corners, copper (galvanic corrosion).

- Choice of appropriate structural material, careful welding (also from the root side), stress relieving heat treatment if necessary.

- Appropriate treatment of stored or lubricating material (e.g. removal of gas moisture).

- Coating of structural elements exposed to corrosion with various coatings. These include enamelling, lacquering, lead plating, tin plating, chrome plating, phosphating, cladding (rolling a corrosion-resistant layer onto the base metal), plastic and hard rubber coatings and other similar surface protection processes.

3. THE TECHNICAL CONDITION OF THE MACHINERY, MAINTENANCE CHARACTERISTICS

3.1. TECHNICAL CONDITION, FUNCTION

Determining and inspecting the technical condition and changes in the technical condition of machinery is one of the most important tasks of machinery maintenance. The technical condition of machinery is determined by various condition characteristics, such as performance, efficiency, energy, quality of work, operation, ergonomics, maintenance. Due to the large number and complexity of the condition characteristics, we are forced to limit them to those that define the prescriptive condition for a specific machine in standards, directives, technical specifications, machine manuals, etc. Let us call these specifically treated characteristics parameters.

By a function we mean a task corresponding to a purpose and the fulfilment of that purpose. It can be seen that in many cases parameter values corresponding to the prescribed condition of the machine or equipment are not necessary, since a lower level of parameters or part of parameters may be sufficient to fulfil the desired function. For example, consider a lathe used to enlarge a forged preform, where the desired function does not require the otherwise higher accuracy of the lathe guaranteed in the machine's manual.

The reverse is only exceptionally the case. In this approach, the prescriptive state means all possible functions, whereas only the required functions are needed to perform a specific task. It is clearly perceived that, for a piece of equipment, it is the functional capability, rather than the prescriptive state, that is decisive, even the ability to perform the desired functions. Failure occurs in the absence of this capability.

Our machines and equipment are complex and can be understood as a complex system. A complex system is a set of interconnected elements that provide a variety of ways to perform predefined functions. A complex system can be broken down into its elements, each of which, in addition to performing a specific function, is interdependent with the other elements of the system. Element means a structural unit, sub-assembly, component or part of a component, generally a component of the system that can be characterised by independent input and output parameters. The notion of a complex system necessarily includes the possibility of different modes of operation with different efficiencies.

The state characteristics vary as a function of time and/or use. The output parameters play an important role in determining the pseudo-potential, which also depends on the structure of the system and the nature of the parameters of the elements. In practice, we usually work with a few, usually composite, state variables, i.e. we try to establish the necessary and sufficient number of parameters.

Technical condition plays a key role in maintenance. In general, the state of a system, characterized by n output parameters, can be understood in terms of an n-dimensional state space, where each point of the system corresponds to a specific point in the state space.

The state variables are in general time-dependent: Y = f(t). State variables that do not vary with time or vary only negligibly are in fact secondary from the point of view of maintenance. These can be, for example, machine stands, components of the machine body, components with high strength and low load capacity.

3.2. CONDITION DETERMINATION, DIAGNOSTICS

The perfect working order of a machine, its proper functioning, can only be judged if we know its operating principle, its construction, its operating noise, its operating speed, its operating temperature, and in general all its operating characteristics. Any phenomena other than normal operating characteristics (strange noises or knocking, loss of power, increase in fuel consumption, warming, etc.) may indicate a fault in the machine, which is not usually easy to detect and requires a great deal of practice. The origin of the fault can be determined from all the detectable fault signals.

Diagnostics is the non-disruptive monitoring, control and adjustment of the operation of machines, vehicles and other equipment to the given operating characteristics. Advantages:

- dangerous situations can be avoided;

- reduce unforeseen shutdowns;

- reduce damage to plant and equipment;

- savings can be made without dismantling machinery in use;

- Easily identify failed parts.

Many faults can be spotted without the use of an instrument, using the senses of a skilled technician. [2] The easiest way to detect a fault is to see it with the naked eye, e.g. loose bolted joints, external cracks, fractures or rotating parts running out of alignment. It is more difficult to detect a fault if it is due to abnormal operation of internal structural components.

An audible sign of a fault may be abnormal machine noise, banging or knocking noises, all of which may indicate that a component is loose or worn, or that the lining metal of a plain bearing has melted. On an internal combustion engine, a knocking sound can also be caused by a faulty ignition. A worn piston in the cylinder will make a chirping sound. Clanking noises can be caused by loose covers or vibration of the slats. The regular repetition of these characteristic noises may indicate a fault in a rotating, oscillating component.

It can also be detected by touch. Minor vibrations and displacements or thermal imbalance that cannot be heard can be detected by palpation.

Overheating or high operating temperatures can also be detected by a burnt smell (oil, rubber, gasket, insulation, etc.).

In-service fault detection is also aided by in-built instrumentation. They indicate the main operating parameters of the machine or the quality characteristics of the work carried out by the machine, and thus also help to diagnose faults.

When measuring temperature, the permissible temperature variation is checked by contact or indirect (thermal radiation). A small thermocouple or resistance thermometer is placed on the surface of the part to be measured. Good thermal contact is important. Radiation-based and thermocamera tests are becoming increasingly common.

The abrasion of oil lubricated components introduces microscopic debris into the oil stream. This debris characterises the wear process and can be used to indicate the condition of the parts.

In a spectroscopic oil analysis, the materials in the sample emit a light emission characteristic of their material quality in the atomic state of the glowing vapour. This radiation is composed of light rays of different wavelengths characteristic of the contaminant elements. In a particle count test, solid particles of an oil sample passing through a slit shade the light according to their number and size, and the changes in the light beam are converted by a photodiode into electrical signals that can be counted or recorded by dividing the beam into ranges of dimensions.

In the activation wear test, the composition of the wear product is inferred from the gamma spectra of the ash produced during the burnout of the sample.

In the ferrographic method, wear products are selected from the sample to be tested using a strong magnetic field and can be examined using an optical microscope or a counting electron microscope.

Excessive vibration is a clear indication of malfunction. Mechanical vibration sensors can be connected to the machine, which, together with an electronic unit, allow the vibration level to be determined over the entire frequency range of the transducer or, with an appropriate filter, over a selected frequency band. Resonance values recommended for the classification of high value rotating machinery depending on the category of machinery are given in standards.

The noise generated by the machine may also be an indication of trouble. The acoustic monitoring equipment is the same as that used for vibration monitoring, except that the vibration transducer is replaced by a microphone placed near the machine. The permissible noise level and frequency spectrum can only be established on the basis of empirical data.

Subjective in-service fault diagnosis may be supplemented by periodic instrumental safety or defectoscopic tests. The technical condition of an internal combustion engine can be assessed by the performance of the components connected to the compression chamber, which can be deduced from measurements of the final compression pressure and the swelling rate of the crankcase. Defectoscopic tests can also be used to check the alignment of the front undercarriage and steering gear, and to check the smoke emission of internal combustion engines.

3.3 MAINTENANCE CHARACTERISTICS

3.3.1. WEAR RESERVE

Functional performance is achieved during operation, while the machine is being used up as necessary. The nature of wear and tear varies widely: it is generally of long duration, not necessarily uniform over time, but can also occur over a very short period of time following sudden changes.

Functional capability is dependent on the machinery being produced with the necessary reserves to perform its function. This is illustrated in Figure 3.2.

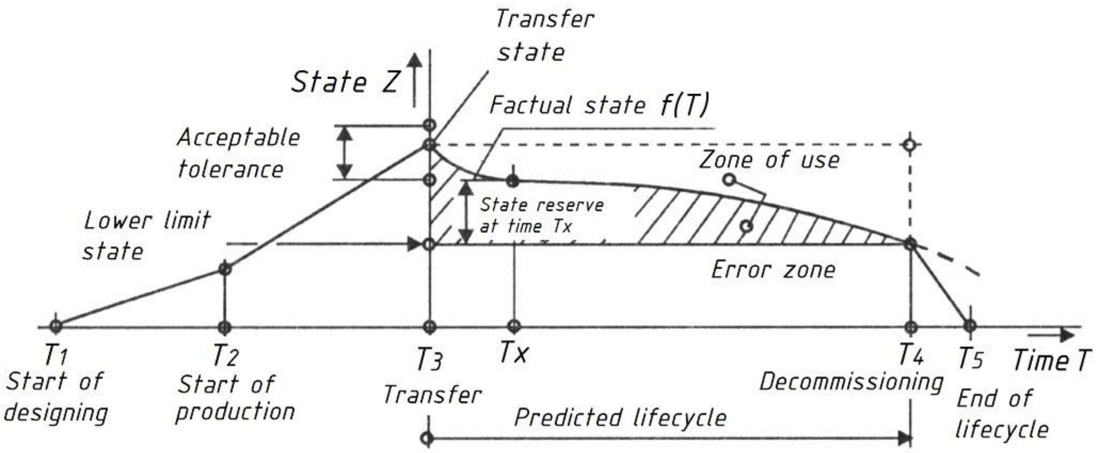


Figure 3.2. Process of Wear Reserve (WR)

A device is manufactured with some acceptable tolerance and then, during its useful life, it remains in working order without repair until the lower limit state is reached. This set of functional performance is called the wear reserve (WR) and represents the machine's use value to the user. (The term wear reserve was originally coined "performance reserve".)

The value of the reserve can be determined, in a fortunate case, by a single characteristic for a machine part, such as the wear rate, but this is rare because of the multi-factorial nature of wear. If the reserve cannot be determined by a single physical characteristic, it is usually referred to as the wear reserve and its value is preferably expressed as a percentage of its initial value (at the time of completion of manufacture).

As far as we know at present, the curve of the variation of the WR as a function of the time of use can only be determined experimentally. For some typical cases, it has already been determined; the character corresponding to the known wear curve has been observed for gear wear, with a linear decrease of the WR for uniform wear, and a monotonic decrease for fatigue wear. Replacement or restoration of the principle set reserve can be achieved in two ways:

- Either the original worn-out device is scrapped and a new one is built in its place as a replacement,

- or, if it is a repairable asset, to restore the spare part using appropriate technology.

The important thing is to find a suitable way of making the worn-out spare part available again. In the case of repairable systems, the conflicting states of wear and restoration may be repeated several times over the lifetime of the system.

3.3.2. THE MARGIN OF ERROR

The WR provides essential information and is of particular importance to the maintainer in the section of the maturity curve preceding the damage limit (failure limit).

a) The value of the failure limit must be known in the form of some manageable parameter(s). Exceeding the lower ha-limit, or an unacceptable loss of functionality, is the basic problem of damage, of fault interpretation. A particular problem is the setting of the limit value, which:

- is known from official and factory specifications;

- The limit values can be imposed on the basis of a statistically valid number of observations; - can be determined from the WR characteristic curve (inflection point);

- is derived from a statistical analysis of the production process;

- can be calculated on theoretical (dynamic, kinematic, thermodynamic) bases.

(b) The maintenance technician is usually mainly interested in the remaining service life, the determination of which is a theoretical but also a practical problem of maintenance. Both the maintainer and the operator are rightly looking for a relationship between the WR (for the machine) and the number of hours that can still be worked, the quantity of products that can still be produced, etc. The other question is how the ratio between the WR actually achieved and the theoretically achievable performance (e.g. product quantities), the so-called utilisation rate, develops once the WR has been exhausted. In addition to the WR, the utilisation reserve can be understood as the quantity of products that can be produced/served under the production/service capacities under the specified conditions, while the depletion reserve is exhausted. Thus, the WR is a fixed quantity and the exhaustion reserve is a target quantity, the former related to the machine and the latter to the output.

4.. THE ROLE OF RELIABILITY IN MAINTENANCE, INDICATORS

Reliability theory is the discipline which defines the laws governing the failure of machinery and equipment, the ways of predicting it, the ways of improving reliability during design, storage and use, and the methods of monitoring reliability. [4]

The beginning of the theoretical study of reliability is linked to aeronautical engineering in the 1940s. For safety reasons, efforts were made to prevent failures by systematically inspecting them. Its more widespread use is typical of the 1970s, when the reliability of large technological systems (notably nuclear power plants, but also complex industrial processes) became increasingly important. As maintenance systems evolved, Reliability Centered Main-tenance (RCM) emerged as an integral part of this development. RCM is a relatively fixed system that aims to be effective in terms of prevention by analysing potential and actual faults, identifying their causes and evaluating their consequences: it focuses on methods, and applies prevention in particular to important machines and equipment that pose a threat to the environment, have serious consequences and have a major impact on production.

Reliability, as it is now classically defined, is the ability of the owner of a piece of equipment to carry out his task under specified conditions and for a specified period of time. In this sense, the concept of reliability refers to only one operational property of a product, namely its fault-tolerance.

Reliability is influenced by other factors in addition to faultlessness. Fault-tolerance is in fact the most important reliability characteristic of products which cannot be repaired and which operate only until the first failure. [4] The vast majority of our machines and equipment, even in their structural parts, are repairable, so it is particularly important to consider other characteristics that are important for maintenance, such as durability and repairability, which have a significant impact on the resulting reliability of the equipment.

The current interpretation of the concept of reliability according to the standard MSZ IEC 50(191):1992 is that reliability is a generic term used to describe serviceability and its determinants, i.e. freedom from defects, maintainability and the provision of maintenance. This reliability terminology is solution-oriented by incorporating the reliability of the product in a general sense into the concept of the quality of the service(s) provided by the product.

The quality of service depends on the various service capabilities (in particular availability and continuity) and the service capabilities depend on the efficiency of the facilities, which in turn have two components: technical performance and usability. Technical performance is the ability of a product to satisfy a given level of service demand under given internal conditions (e.g. some combination of faulty and non-faulty components). Serviceability is the ability of the product to perform its intended function at a given time or period under given conditions, provided that the necessary external resources are available.

The ability to provide maintenance is the ability of the maintenance organisation to maintain the product under specified conditions and using specified procedures and resources.

Quantitative values can be assigned to the capabilities that characterise reliability and the time concepts that describe them using metrics. These metrics (variables) can be determined using probability and mathematical statistics due to the random nature of reliability events.

The evolution of the failure rate may vary during the typical stages of the life cycle and its sub-variety is characteristic of the failure behaviour of machines and structural parts (Figure 3.6).

The decreasing or increasing nature of the initial and late stages (the so-called bath-tub curve according to type C) often does not occur (e.g. the element does not age or the commissioning is not carried out), but the existence of a normal stage is almost common, with a pseudo-landing average failure rate.

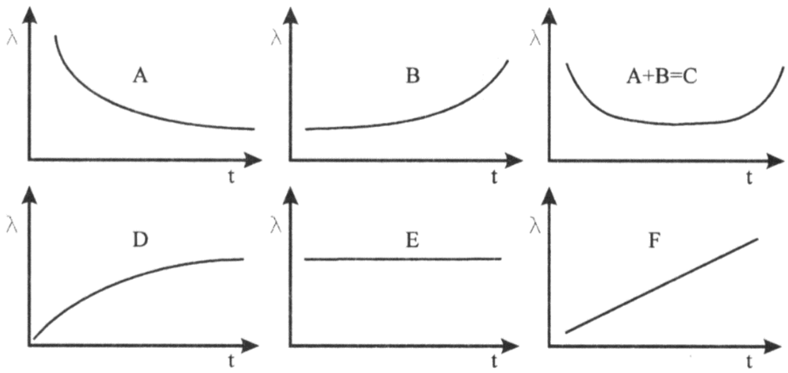
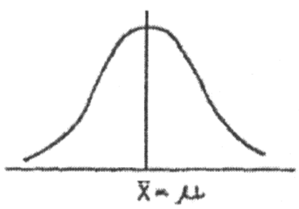
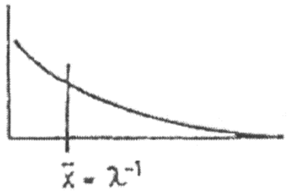
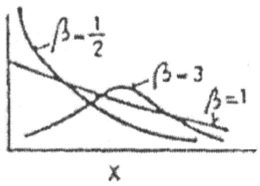
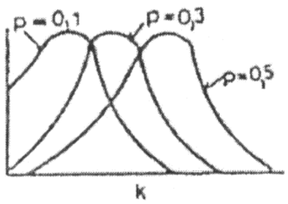
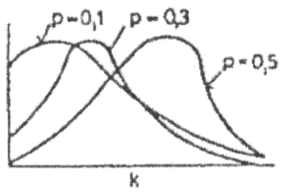


Figure 3.6. Evolution of failure rates

Known correspondence of phenomena and distributions Table 3.1

Type of distribution	Density function shape	Phenomena that can be described by the distribution (problem)
Normal		- mass phenomena, where the process is influenced by many different, independent factors (e.g. life cycle of components, manufacturing defects, ageing, wear, corrosion), - data from a set of distinct samples with the same number of elements (regardless of the distribution from which they are drawn), - a set of independent, large numbers of probability variables with the same distribution, - aging phenomena of machines,

		- the actual operation until failure of products which cannot be repaired, - gradual failure of machinery due to friction processes.
Exponen-tial		- failure rate analysis of complete systems and machines, - failures resulting from a purely accidental event (e.g. a stone hitting a windscreen), - unexpected and irregular damage flows.
Weibull		- indicators for certain components or machines (e.g. lifetime, failure), - in the case of coincidental and regular failures, the actual (fault-free) operating times between failures.
Binomial		- sample checks, - for discrete probability variables, - probability of a machine failure in the case of independent failures.
Poisson		- the number of failures of complex systems over a given period, - simultaneous arrival of machines for repair, - number of foreign particles in homogeneous material.

4.1. RELIABILITY OF THE MACHINERY SYSTEM

In engineering practice, it is relatively rare to limit reliability testing to the analysis of single points of failure, since complex, complex equipment built up from a large number of structural units with a large number of points of failure also requires reliability testing.

Reliability theory essentially applies to machinery the same parameters that it has introduced for failure modes, but the calculation of these parameters is usually a much more complex and complex task for machinery.

The more failure points the machine under test contains, the more difficult it is to achieve adequate reliability. It is necessary to know the reliability parameters, the repairability and the interactions of the failure modes that make up the machine systems. [4] We also need to know the extent to which the failure of each failure point influences the failure of the others.

Independent failure modes are those systems where the failure of one failure mode does not affect the reliability of the others. The reliability of systems consisting of independent failure modes and operating until the first failure is well described by the probability of fail-safe operation: the reliability function of n elements R1(t),...,Rn(t). n elements can be connected in series, in parallel and in mixed mode.

We consider a series connected system to be a reliability connection of elements such that a failure of any one of them causes the system to fail. In such a case, the resulting reliability

R(t) = R1(t)R2(t)...Rn(t) = Ri(t)

In the case of a system with parallel connection, the elements are independent with respect to reliability, i.e. only the failure of all the elements causes the system to fail:

R(t) = 1 - [1 - Ri(t)]

In a mixed connection system, there are both series and parallel connected elements. The resultant of a mixed-circuit system can be broken down into elementary connections to determine the strengths of the groups of elements, and then the system is progressively reduced to a single element (the resultant). The reliability and failure functions described above can only be used in cases where the test is carried out up to the first failure or (equivalent) where the elements cannot be renewed.

5. FAULT ANALYSIS AND FAULT RECTIFICATION

A failure is defined as a condition in which the machine cannot perform its intended function, or has no wear reserve (WR) that can be used to perform its function. In a fault condition, the WR is partially or totally lost.

Failures cause significant disruption and losses in production systems, and it is therefore necessary to analyse the processes, causes and consequences of failures in depth. There are methods to detect potential failures that have not yet occurred, and others to analyse failures that have already occurred.

IEC 50 (191):1992 introduces the methods of failure analysis for the former and failure analysis for the latter. The so-called weak-point analysis method can also be connected to these.

In addition to the term failure analysis, the term damage analysis is also used in the literature. Since failure leads to partial or total inoperability, damage, the use of the word damage (type of damage, damage) is also entirely appropriate.

There are an infinite number of damage states between nominal or new pseudo-potential and failure. Damage effects are multiple, usually of a stochastic (accidental) nature and closely related to each other. Overcoming these effects in the design, manufacture, use and maintenance of the structure, and eliminating their impact in the restoration process, requires a precise knowledge of the causes and forms of damage.

In practice, three types of failure can be distinguished according to the duration and extent of the failure (Figure 5.1):

- gradual failure, which occurs continuously (e.g. due to a condensation phenomenon) from the beginning of the operation (type A, "soft failure");

- Delayed failure: the failure mechanism is triggered randomly at a later point in time by some unforeseen event (e.g. a cut-off) and then develops its effects gradually (B-sign);

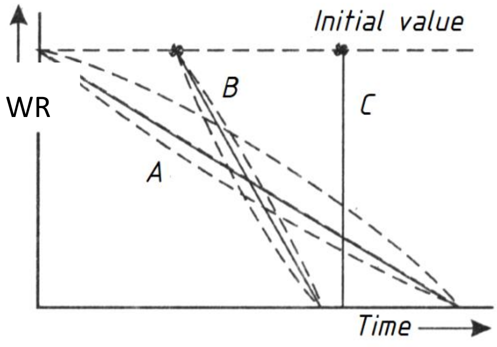


Figure 5.1. Failure types

- a sudden failure (e.g. a pneumatic hose fitting puncture) causes a partial or complete failure at a random time (C-sign, "hard" failure).

5.1. FAILURE AND MALFUNCTION

According to ISO IEC 50(191):1992, a failure is a condition of a product in which it cannot perform its intended function, unless this condition occurs during preventive maintenance or other planned activity, or is due to a lack of external resources. Thus, the product goes from a working state to a failure state after failure, and the failure is also understood as a process.

From the initial state, a process of wear and tear can be interpreted as a result of various stresses and damaging effects throughout the entire period of the operational state. The original or restored WR is continuously reduced by wear and tear and, through the failure process, approaches the failure limit (WRf=0), where the failure state is reached, which in most cases does not mean the loss of all the machine's functions, but only the loss of the desired functions. Further wear and tear that follows will cause a complete loss of functionality of the machine, leading to a state of inoperability.

In the course of wear and tear, various failures (technical failures which do not represent a failure of the system as a whole) may occur affecting the components of the system (machine). In assessing the failure process, the following conclusions can be drawn:

- various technical failures occur in the process for some reason,

- the resulting technical failures vary in their manifestations (wear, stretching, deformation, cracking, fracture),

- they interact, but only one of them causes a malfunction or a change in quality.

Failure is therefore an indicator of a change in the quality of a component or part during operation. The change is the result of a cause or causes that can be determined and, as a result, is interpreted as an oc¬osity. Failure is indicated by the number of changes involved in the process, which reduce the technical reliability of the component or sub-assembly and affect its serviceability. Failure is therefore not the same as a technical defect, since a technical defect can also occur during manufacture or repair, where it is not necessarily a failure. Technical failure is merely a precondition for failure.

Although undesirable, failure is a necessary and natural part of operation. Reliability is linked to failure, because if a structure does not work as intended, it is bound to fail. Logically, the higher the reliability, the lower the probability of failure.

The notion of failure becomes complete when considered in conjunction with reliability. Knowing the two main concepts, we can now say that failure is a process that occurs as a result of deterioration or deterioration of components or sub-assemblies during operation and reduces their technical reliability.

From a practical point of view, it is important to define the relationship between some concepts.

- Technical unreliability is defined as the failure of a component or sub-assembly to perform its functions properly under certain operating conditions for a specified period of time. This condition does not always lead to failure. For example, a worn tyre on a tractor may work reliably on dry ground, but on wet ground it slips, makes traction impossible, and is unreliable.

6. MAINTENANCE STRATEGIES

Many different forms of machine maintenance (product aftercare, servicing) have evolved, basically with the aim of maintaining the repair, during and after the warranty period, of the products made by different companies, i.e. their operational condition. Which of these is the right answer is not easy to answer, because it is necessary to coordinate several aspects in order to assess the market demand for a given product in terms of maintenance. For a given product, the main questions are:

- what is the market penetration of the machine in domestic and international terms,

- the maintenance needs of the operators,

- what are the equipment and instrumentation requirements for machine maintenance,

- whether the design is based on replacement or refurbishment,

- the spare parts supply of the machinery concerned,

- how environmental considerations can be met.

It is also clear from the above that the forms in which machinery maintenance is carried out are also dependent on the level of demand, since if a product ceases to be manufactured, after a certain period of time it will also become necessary to replace it. On the other hand, when a new product is launched on the market, its after-sales service must also be taken into account, as this factor can have a significant impact on the competitiveness of the product on the market.

The ways of implementation can be grouped into long-term, strategic, and short-term, tactical. The former includes maintenance regimes (corrective, corrective replacement, planned preventive, preventive maintenance, preventive maintenance and total maintenance), while the latter includes short-term solutions.

6.1. MAINTENANCE SYSTEMS

Given that the failure of machinery, equipment and individual components, their repairability, the consequences of failure and the technological options available can be extremely varied, a number of different maintenance systems have evolved. Taking account of economic requirements, the following systems can be used to ensure the serviceability of machinery:

- on-demand maintenance and repair (point-of-failure replacement, "fire-fighting"),

- planned preventive maintenance (PPM) (time-based or performance-based),

- maintenance based on technical condition testing (diagnostics),

- Total Productive Maintenance

- Reliability Centred Maintenance (RCM)

6.1.1 MAINTENANCE AND REPAIR ON AN AS-NEEDED BASIS OR AS A REPLACEMENT FOR A DEFECT

In this maintenance system, repairs are only carried out after a failure has occurred. The failed component or main part is repaired or replaced with a new one. Care and lubrication operations must also be carried out regularly in this form of maintenance.

Its advantage over other maintenance systems is that certain parts and components of the equipment can be used to the limit of their wear and tear.

The disadvantage is that the intervention and repair time cannot be planned in advance, so the downtime is usually longer depending on the load on the repair capacity, as their load is unplanned and highly variable.

Immediate replacement of unexpectedly failed machinery is usually not possible and therefore usually causes problems, and late detection of unexpected failures can create further deterioration between components. Accordingly, a relatively large stock of spare parts is required to ensure timely rectification of the fault.

The above may result in high maintenance costs.

Necessary repairs should be used only in cases where the impact of the above-mentioned drawbacks is minor. These are:

- no data are available on the expected occurrence of the failure,

- the failure does not pose an accident hazard,

- the loss of production due to an unexpected failure does not represent a major financial loss,

- failure to detect the fault in time will not cause further damage,

- the fault can be easily and quickly rectified by the operator,

- spare parts can be stored during operation in order to rectify the fault within a short time, and the relatively large quantities of spare parts stored do not cause major financial burdens.

In summary, the use of on-demand repair is primarily appropriate for simple machines with low complexity.

An analysis of maintenance-related costs has already shown that, depending on the installation, around 60% of maintenance and repair expenditure is due to damage and loss caused by frequent faults. In other words, an analysis of the "life history" of the equipment shows that a considerable proportion of breakdowns are not caused by wear and tear, but by a large number of faults in the manufacture and installation of the equipment.

The industrial research institutes involved in these studies are looking for a new maintenance strategy to replace the current systems, the aim being to identify and eliminate probable faults. This strategy is justified by the fact that, at present, the costs of maintenance can hardly be reduced, while hi-maintenance sites can, in theory, be almost completely eliminated.

Few companies have yet realised that the time and costs involved in preventing faults are much lower than those involved in actually repairing the faults that occur. Most companies' machine maintenance is characterised by the fact that they consider it more important than maintenance considerations not to exceed the (often tight) budgeted procurement margins. Little attention is therefore paid to the operating costs that may be incurred in the operation of equipment chosen at the cost of trade-offs.

In addition to the scarcity of financial resources, investors are also forced to compete on time. In many cases, the process of preparing and making a decision is long, and they try to compensate for this by shortening the time taken to get the plant up and running. There is not enough time to identify the faults and weaknesses of the new equipment, which can multiply the subsequent maintenance costs. In order to reduce maintenance, the following three requirements for new installations should be observed:

- before putting new machinery or equipment into service, any faults identified should be rectified,

- to identify and eliminate as many "childhood diseases" as possible through a careful commissioning process,

- detect any remaining defects and faults within the warranty period (3-6 months).

Surveys have found that the established maintenance organisations are not yet functioning as organisations responsible for fault prevention. Another obstacle to the introduction of the concept is that the costs of maintenance are not well measured in many places, and any analyses carried out often lead to erroneous conclusions.

The actual maintenance costs include, among others: technical inspection, care and maintenance, refurbishment, repair of worn and worn parts. However, there are some typical errors in the definition of these costs and in their separation:

- the additional costs caused by the faults and weaknesses of the machinery are not correctly separated from the actual maintenance costs,

- these costs - caused by the failure points - are only possibly recorded,

- the precise identification of the maintenance costs incurred is often not carried out (broken down by machine, by failure),

- variable and fixed cost elements are often identified together.

The analysts also suggested that maintenance orders should be highlighted as those requiring repairs or troubleshooting due to known weaknesses in the equipment. This new approach does not require additional numbers or greater expenditure for the majority of companies.

It is an established organisational principle that the chief maintenance officer should monitor the weaknesses of both existing and new equipment.

The concept of failure detection precedes breakdowns by analysing each potential failure point and, based on the analysis, prescribes measures to avoid or at least mitigate the resulting losses. These measures also entail costs, but the costs involved are substantially lower than the costs of maintaining the plant.

The probable points of failure should be anticipated in sufficient detail in the design of the equipment so that the costs of production and warranty repairs can be reduced substantially.

6.1.2. PLANNED PREVENTIVE MAINTENANCE (PPM)

Industrialised countries have recognised the importance of maintenance from an early stage. As a result, planned preventive maintenance (commonly abbreviated to PPM) has been introduced to replace the previous system of simply repairing faults that have occurred. This maintenance system focuses on preventing faults and eliminating unforeseen breakdowns.

The PPM system is widespread in industry, services and public transport. In all these industries, regular and preventive inspections and repairs have been carried out in technical practice since time immemorial. For example, the foundations of the maintenance system for railways date back more than 100 years and have been refined on the basis of many years of experience.

The permanent operational condition of machinery, equipment and rolling stock is achieved by regularly scheduled inspections and repairs. Inspections and repairs are carried out in accordance with a rigidly defined maintenance schedule - the cycle schedule - which includes

the type and extent of work carried out, the sequence in which they are carried out, and the other parameters (time, performance, etc.) and their magnitude between inspections and repairs.

During maintenance, he/she would take care of the care, maintenance, inspection, necessary adjustments and other repairs of the machines. Repairs, on the other hand, involve the partial or complete dismantling of the machine and the repair or replacement, irrespective of the extent of the failure, of parts or components whose remaining life is likely to be shorter than the time until the next repair. This measure is intended to prevent unexpected failure before the next scheduled repair. In addition to repair, renovation may also involve modernisation, new utility and advanced technical standards.

Under the PPM system, equipment is taken out of production on a scheduled basis, thus reducing the cost of unexpected breakdowns and balancing the repair workload, while at the same time avoiding the unnecessary loss of time and money by replacing parts that are still in working order.

In general, the PPM system has the following tasks:

- to develop a repair system which, knowing the stresses and life expectancy of the components, seeks to prevent failures proactively, thus ensuring the continuity of the plant within the tolerated time,

- designing a repair system where the starting and finishing dates of repairs can be estimated in advance,

- the establishment of a maintenance and repair organisation which, if it operates correctly, will keep machinery and vehicles out of productive use for the shortest possible period, and

- the organisation of repair work in such a way that production is not altered by the machinery and vehicles being taken in for repair,

- to ensure the quality of repairs so that the serviceability of machinery, equipment and vehicles is satisfactory at all times,

- modernisation of equipment, which reduces the repair work, reduces the cost of the equipment, improves the performance of the equipment and improves the quality of the product.

In summary, PPM's task is to maintain reliability, the target level of which is determined by the necessary safety and economic considerations.

The advantage of a PPM system, provided that a well-established and correct cycle schedule is established, is the ability to plan repair tasks over a longer time interval, to reduce the resulting downtime and to increase the service life of machines and vehicles.

In areas where it is important to maintain a specified reliability value and where there is not yet adequate diagnostics, this method can provide the best results.

The above results can only be ensured by a cyclical approach based on continuous research prior to implementation and during operation.

There are two basic types of maintenance cycles:

- time-based (time-dependent), which does not take into account the actual demand,

- performance-based (performance-dependent), which adjusts the time of interventions to the demand.

The economic impact of PPM can be easily measured by the reduction in production costs, the increase in the lifetime of machinery and equipment and the reduction in scrap for machinery in good working order. A the work of the machines and vehicles, which are maintained according to plan, is almost uninterrupted, and there are hardly any breakdowns. As a result, the repair cost per unit of production and the repair cost ratio of the production cost are reduced.

In summary, the use of a PPM system is essential for the reliable operation and pseudo-failure prevention of complex and high-value equipment.

6.1.3. PREVENTIVE MAINTENANCE BASED ON TECHNICAL CONDITION TESTING (DIAGNOSTICS)

Preventive maintenance (PMM), which follows a relatively rigid maintenance cycle, is based on the analysis of component wear and tear and the resulting laws of logic. However, the wide range and detailed analysis of rapidly evolving engineering and operational data does not always provide an accurate answer to the question of component durability, failure-free operation and life cycle.

The service life of components is influenced by many factors, including the quality of manufacture and repair, highly variable operating conditions (loads), premature dismantling, careless maintenance, etc. The expected service life is uncertain if the component is made of new materials with little known history, the equipment is new, there is no operating experience, etc.

The quality of manufacture and repair depends, among other things, on the accuracy of machining and fitting, surface quality, heat treatment and care in assembly.

The operating conditions are determined by the weather, the environment (dust content, humidity, etc.), changing and often unforeseen stresses and the handling of machinery. Because of the many factors that increase uncertainty, it is advisable to establish a maintenance system that determines the time for maintenance and repair on the basis of periodic or continuous instrumental technical condition tests (e.g. measuring the wear of components) during operation and ensures that the equipment is in a fit state for use.

With the appropriate measuring and recording equipment, the instrumental technical condition test (technical diagnostics) can be used to determine the wear characteristics of individual components and sub-assemblies (e.g. compression pressure, vibration, insulation level of electrical equipment, position of bearings, valves, other electrical faults, etc.) without dismantling.

Regular monitoring of the technical condition of the machinery and evaluation of the results of the monitoring will help to understand the laws of wear and tear. Knowledge of the wear and tear patterns will make it possible to determine in advance when and to what extent repairs will be necessary.

For example, in internal combustion engines, the compression end pressure decreases in proportion to the wear of the cylinder and piston, which depends on the power and operating conditions. Knowing the wear rate, the wear rate allowed for economical and serviceable operation and the compression pressure associated with the wear, the repair date can be determined in advance.

In other cases, the amount of wear product in the lubricating oil, or the increase in wear product compared to the previous measurement, can be used to infer the extent of wear.

The condition of the oil filter is characterised by the difference between the pressures measured before and after. The condition of the integral roller and plain bearings can be monitored by vibration measurement. Measurements of the parameters of the electrical active and passive components - or the amplifiers, filters, modulators, demodulators they are made up of - provide information on the current state of the component or module and on the need for and time of re-setting or possible repair.

The unexpected failure of increasingly sophisticated, but more productive and relatively expensive machines, produced as a result of technological progress, leads to ever greater losses. A maintenance system based on a technical health check can help to reduce the extent of this downtime.

The availability of regular information on the technical condition of machinery and equipment not only reduces the number of unexpected breakdowns, but also increases the cycle time between overhauls and reduces the number of overhauls. Depending on the nature of the machinery, equipment or vehicle and its role in the production process, major overhauls in the classical sense may be dispensed with.

The system provides the right information for planning. The choice and quantity of the parts required for the repair can be determined on the basis of the expected failure rate, thus ensuring optimum stock levels. The number of repairers and maintenance staff required in each period can be determined on the basis of the expected repair isme-rate, and the legal and actual preparation of maintenance work by external companies can be made.

A preventive maintenance system based on diagnostic tests will provide the opportunity to increase the organisation of repairs, to introduce more modern repair methods such as the replacement of main parts and the replacement of functional units (modules) for equipment that is subject to replacement.

On the basis of the above, the establishment of a maintenance system based on a technical health check appears to be the most economical, but its effectiveness depends to a large extent on the quality of the diagnostic methods and the error of the forecasts.

The procedures and methods of technical condition analysis (diagnostics) are very diverse. Some test methods are considered traditional and are in general use, others are only occasionally used in practice.

Traditional procedures include: length measurement, pressure measurement, temperature measurement, flow rate measurement, mass (flow through mass) measurement, force measurement, power measurement, torque measurement, electrical measurement, hardness measurement, etc.

New methods not yet in general use: vibration measurement, vibration analysis, pulse measurement, ultrasonic methods, sound source analysis, noise measurement, stethoscopy, radiography, radioactive isotope applications, potential probe methods, magneto-pore methods, endoscopy, spectroscopy, pulse counting, photogrammetry, etc.

The third group of techniques includes methods whose theoretical foundations have been established but which require further laboratory development before they can be applied technically and economically in practice. This group includes, for example, holography with its four main directions, holographic optical imaging, holographic interference measurement, holographic data processing, acoustic and microwave holography.

A further obstacle to the uptake of technical condition testing is the scarcity of mechanical diagnostic equipment available today. This is reflected in the fact that

- in most cases, considerable dismantling is required to apply technical diagnostics,

- the accessibility of the connection points to the diagnostic sites is difficult,

- the mechanical equipment does not have test equipment connection points,

- the size and shape of the connection points are not standardised,

- quality and safety characteristics important for operation can only be partially checked by technical diagnostic methods.

Technical health checks may be carried out at specified intervals or continuously. The former is also called the search method. In more sophisticated systems, the tests are carried out by an automatic machine according to a predefined programme, which first measures the main characteristics and then, if it detects a fault, proceeds to more detailed tests.

In the continuous test, the so-called indicator method, instruments and data recorders mounted on the machine or equipment continuously measure and record (e.g. on magnetic tape after an analogue-to-digital converter) the parameters indicating the technical condition. These characteristics are evaluated at specified intervals by a computer which, after comparative analysis, indicates the time, extent and probable causes of the expected failure.

The cost of introducing diagnostic tests for maintenance purposes is relatively high. However, it is justified in cases where the equipment:

- is of particularly high value and complexity, and the cost of downtime due to failure is high, or

- high reliability requirements.

6.1.4. TPM

Total or complete maintenance is a concept that has become familiar in Japanese industry, the content of which is essentially preventive maintenance involving all employees in the form of small group activities.

The modernisation of maintenance in Japan began in 1951 with the transfer of preventive maintenance from the USA. Its first user was Nippondenso Co Ltd, part of the Toyota group, the largest Japanese manufacturer of automotive accessories. In 1960, the company introduced American-style preventive maintenance, whereby operators produce and maintenance is carried out by the maintenance staff. As production processes became increasingly automated, maintenance became critical. Traditional maintenance staff were no longer able to maintain the increasing number of automated machines. The company decided to make the operators responsible for the routine maintenance of their own machines.

Nippondenso had already introduced a system of quality circles in which all employees participated. This experience was also used to develop total maintenance.

These are included in the 12 steps recommended for the development of the programme:

- Improve the utilisation of each machine;

To do this, it is advisable to set up planning teams to identify the tasks needed to eliminate losses and optimise the use of each piece of equipment.

- autonomous maintenance by operators should be introduced, using a small-scale activity using the step-by-step method;

- establish a system of planned maintenance in the maintenance department, with the necessary scheduling, provision of spare parts, tools, technical instructions, etc;

- introduce a training programme to improve the production and maintenance readiness of operators and maintenance staff;

- establish a system for the design and manufacture of reliable, maintainable and economical life-cycle cost machinery and equipment.

The "five essential elements" (steps 7-11) can only be introduced after proper preparation. A detailed plan should be developed on when and in what order to proceed. While the time needed varies from company to company, the preparation phase usually takes 3-6 months and the total time needed for implementation 2-3 years.

The seven-stage system for implementing the system is illustrated in Table 6.2. The worker is assessed by managers or technicians at each step. If a step is judged to be completed, a certificate is awarded and the worker moves up one step. During this process the quality of the equipment has also improved.

The number of unexpected equipment failures at Nippondenso has been reduced from one thousand to twenty per month. Equipment utilisation has improved by 50%. The failure rate in the production process has been reduced from 1.0 to 0.1. The number of complaints has decreased by 75% and the cost of arm maintenance by 30%. Standby inventory halved, productivity increased by 50%.

TQM (Total Quality Management) is conceptually related to the concept of total maintenance, which means that the entire management process is covered by a quality approach, from purchasing to sales, i.e. from the quality of the raw materials, semi-finished products and components supplied to the quality and quality of the sales staff and personnel.

Both are in fact a management philosophy that requires continuous data collection and evaluation, and that decisions should be based on this and not on opinions and assumptions. Involving people in the process is essential.

This new management philosophy means change:

- changes in vision, changes in strategy;

Customer satisfaction becomes the measure of performance.

- Changes in the manager-employee relationship;

Increase in subordinates' knowledge, decision-making, autonomy, creativity.

- changes in formal structures;

The consistency of planning, organisation, stakeholder, organisation and information systems becomes crucial.

6.2. ESTABLISHING A MAINTENANCE CYCLE

It is natural for machinery equipment to gradually lose its usefulness during its service life until it eventually fails and becomes inoperable.

The wear and tear of machinery, equipment and vehicles depends on the failure process of their components. Failures are primarily a function of operating conditions. The two most important factors influencing the frequency of failures are the time of use and the performance.

The magnitude of failures and their consequences can vary widely. The reduction of breakdowns and downtime can only be achieved by well-organised prevention. In order to maintain a certain level of quality and reliability, machines and vehicles must be regularly inspected and, if necessary, repaired. The determination of the uptime (cycle time) is one of the planning tasks of machine maintenance and is intended to provide an answer to the question of the intervals at which a given machine should be taken out of production in order to restore its continued operability.

The system of successive inspections and repairs is called a cycle schedule, the time between them is called the cycle time. The principle of the design of the cycle schedule is illustrated in Figure 6.6.

The cycle schedule includes the frequency of maintenance, the sequence of inspections and repairs to be carried out, the type of work to be performed, the details of the work to be carried out and the parameters (time, km, etc.) between repairs.

The maintenance cycle schedule is developed using different methods. One of the best-known methods of determining the cycle time is to study the wear and tear (service life) of components, another is to carry out economic calculations to assess maintenance costs.

The sequence and timing of interventions should be determined in such a way as to prevent expected failures. This is based on the processing of experience gained during operation, maintenance and repair.

It is relatively straightforward to determine machine repair cycle times and technologies when the variation of the state variables representing the serviceability during operation is deterministic.

In practice, the majority of machine failure modes are stochastic in nature, due to the technical variation of the machine's specifications and thus its degradation during operation, the inhomogeneity of the materials used, the inaccuracy of the manufacturing technologies, and the variation of the stresses.

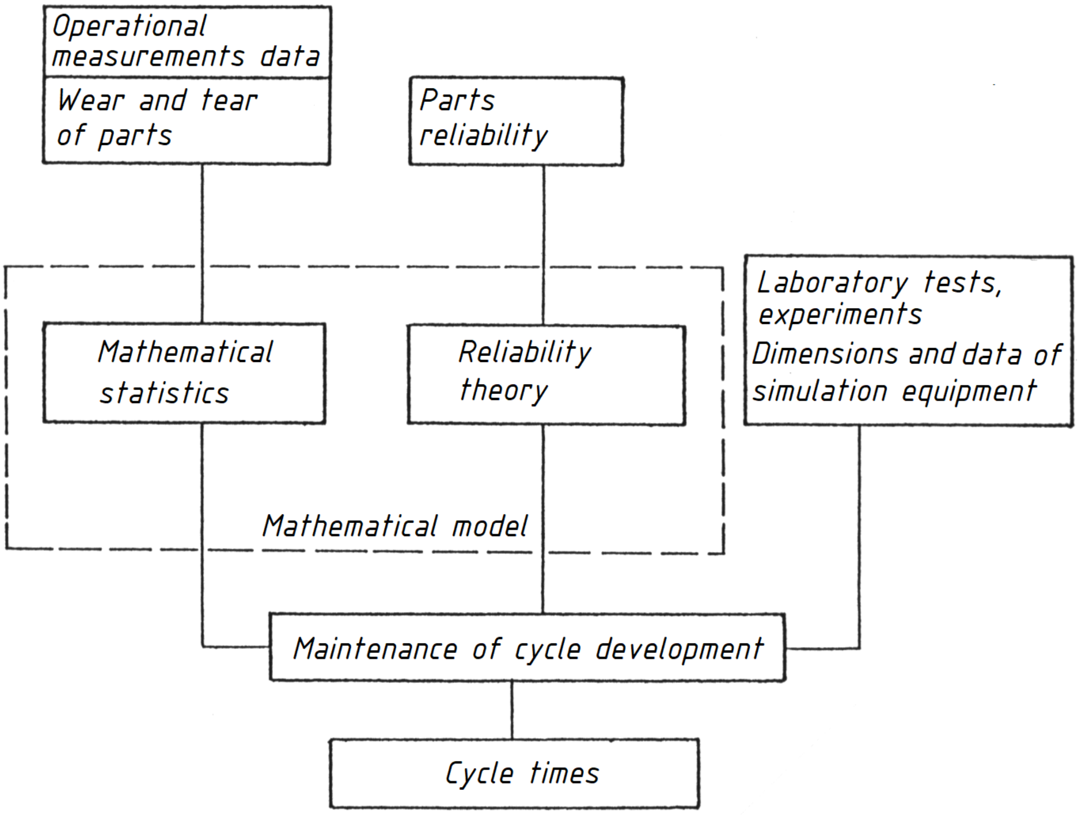


Figure 6.1. Ways to design a maintenance cycle

7. MANAGEMENT OF MAINTENANCE

National and international experience shows that in recent years there has been remarkable progress in the way maintenance is organised and managed. Of course, not all results can be generalised. The type of repair and maintenance strategy and management system used in a company is determined by a number of factors, the most important of which is the technical and technological level of production.

7.1. THE BASIC CONCEPT OF A MAINTENANCE MANAGEMENT SYSTEM

The system is structured in principle around three modules, the functions of which are as follows [3].

The first module is the technical and cost information system for maintenance, which is essential for the rapid and realistic feedback of operational data.

The second module is spare parts management, which provides answers to questions such as:

- which spare part belongs to which machine, equipment or part?

- are there other spare parts available?

The third part deals with planning and programming and uses the information provided by the previous two modules. The module is responsible for the management of human and material resources for each piece of equipment and the planning of maintenance procedures [3].

The most important of the programming and management tasks is the definition of the tasks, the time needed for each task, the deadlines, the issuing of the orders and the recording of the various deliverables.

7.2 IMPLEMENTATION OF THE MANAGEMENT SYSTEM

Management covers three main activities in terms of its operating mechanism:

- issuing instructions,

- giving instructions, returning information and providing feedback to the managing body,

- corrective intervention in the executive process on the basis of a comparison of the information with the instructions.

In this sense, in the management system, the

- decision,

- control

- and control functions.

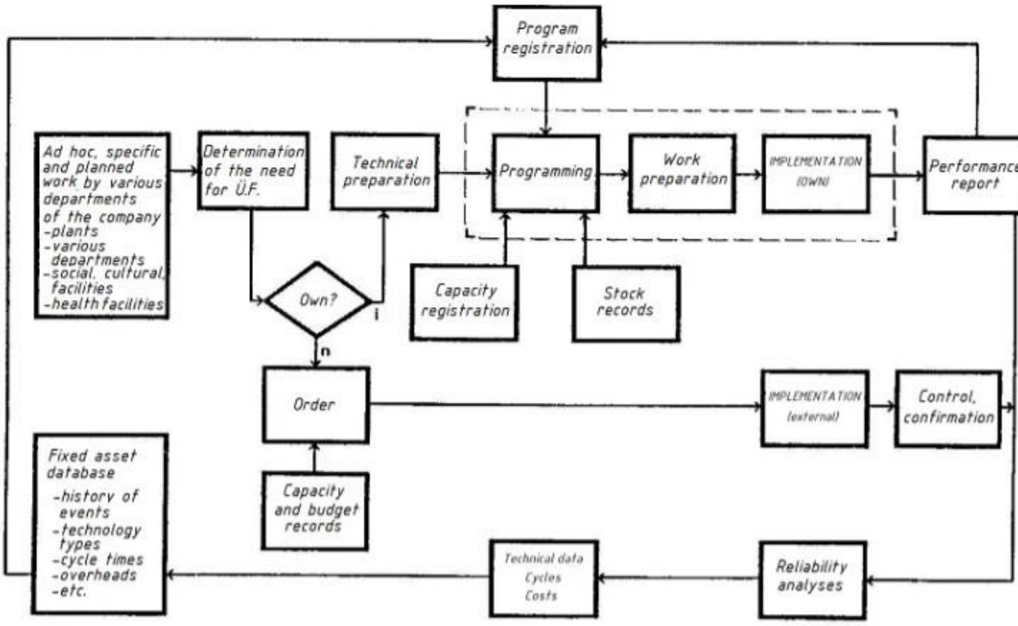


Figure 7.1. Possible outline of a maintenance management system

The process starts when maintenance needs arise, which sets the management system in motion. These needs can basically be of two types:

- planned (predefined) and/or

- ad hoc tasks.

The needs to perform scheduled tasks are automatically generated on a monthly basis from the fixed asset central database. Ad hoc needs may arise partly from the various departments and partly from external sources. These may be repair, in-house investment, spare parts production or service tasks.

Work orders are drawn up on the basis of these requirements and are assessed by the maintenance/operations department to determine whether the work can be carried out in-house or whether it is better to outsource some of the work.

Orders for work to be carried out in-house are subject to technical preparation. Here, the prerequisites for the work (drawings, permits, spare parts, etc.) are provided in accordance with the priority of the works. A monthly programme should be drawn up for the completion of the preparatory work. An advanced level of public management can be achieved by directly providing work vouchers for the preparation and execution of these works. These worksheets, in addition to a clear description of the activities to be carried out, also provide for the use of parts and the vouchered execution time.

Direct feedback after the tasks have been completed ensures the operation of the control function. On the basis of the tasks performed (performance accounting), the programme records can be continuously updated, and on the basis of the repairs carried out (planned and corrective), equipment reliability analyses can be carried out on an ongoing basis, allowing the maintenance cycle times, costs and overall fixed asset database to be updated, including the history of equipment events.

In another branch, the presented management system handles repairs using external capacities. In this branch, the management system is arithmetically simpler, since the operational organisation of the works is the responsibility of the external contractor. At the same time, however, in the interests of uniform management, the placing of orders and the technical and professional monitoring of the content of the works must be ensured.

The repair work carried out using in-house and external capacity is brought together again at the stage of the clearance of accounts, thus ensuring uniform management.

The management system does not appear to include a planning function. However, it should be noted that reliability studies either confirm or challenge the maintenance cycle times applied and recommend revisions. In this approach, repair work is therefore planned. Reliability analyses assess if the equipment has moved beyond stable operation and into the range of obsolescence. Thus, a decision situation is created regarding the refurbishment or decommissioning of the equipment. In the first case, a planned workload for the maintenance organisation is triggered, and in the second case, a scrapping and machinery procurement plan is prepared.

In the management system, the section specifically framed is the area of operational documentation.

7.3 INTEGRATED MANAGEMENT SYSTEMS, CMMS

An integrated maintenance management system ensures that the technical and organisational measures taken to keep production equipment in good working order are properly exploited. The system not only schedules routine or preventive maintenance tasks, but also covers all areas that have an impact on the efficient use of the resources available for maintenance.

Modern technical record-keeping and the organisation and management of maintenance are difficult to achieve without the use of computers and using only traditional manual methods. All of these tasks are linked to the collection, storage and processing of information, and therefore provide ample scope for the use of IT tools and computers [6].

Examples of maintenance management problems include:

- determining the types of spare parts required and their reasonable stock levels,

- monitoring the condition of production equipment at all times,

- anticipating as far in advance as possible the occurrence of an expected breakdown situation,

- determining the optimum time for maintenance and the range of tasks to be carried out,

- full preparation of planned maintenance, so that all the necessary data, tools and equipment are available when the work starts,

- rapid evaluation of the results of periodic monitoring measurements and the drawing of the correct conclusions, etc.

All these problems can be solved by the operation of properly designed and computerised maintenance and repair systems [6].

A fundamental characteristic of management systems is that they must be built from the bottom up. Our approach is that the use of the computer in maintenance should not create "data silos". A management system should be designed as necessary, not as possible.

REFERENCES

1 József Janik: Gépüzemfenntartás I-II. Dunaújvárosi Főiskolai Kiadó, 2001.

2 Sándor Dúll. YMMF aid book, Debrecen, 1994.

3 Christian Eichler: Planning maintenance.Technical Book Publisher, Budapest, 1982.

4 Zoltán Gaál - Zoltán Kovács: Reliability, maintenance. Veszprém University Publishing House, 1999.

5 Emil Vadász: TMK pocketbook. Technical Book Publishing House, Budapest, 1985.

6 Voyager - an integrated condition-based maintenance environment. Delta-3N Ltd.

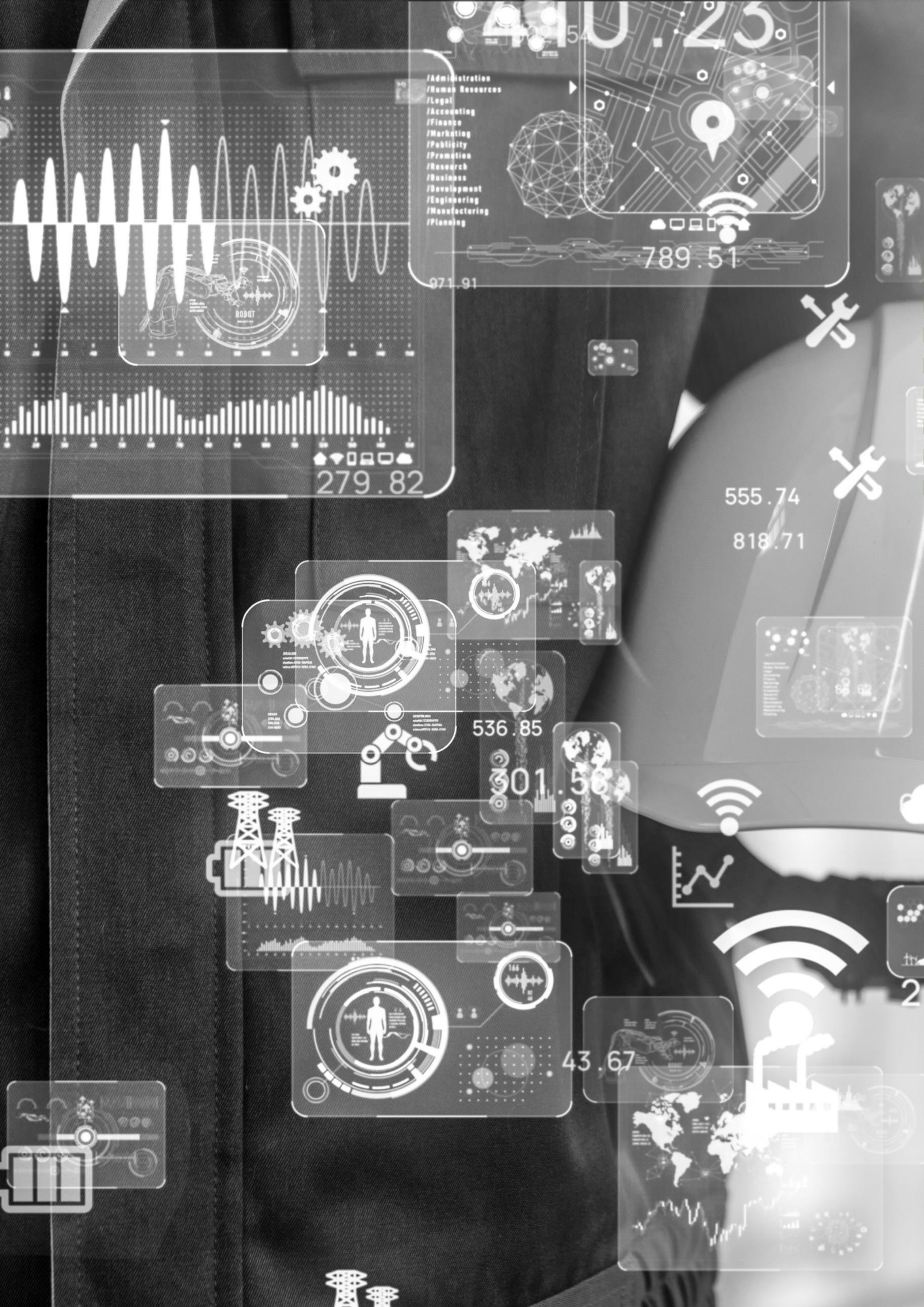
Module_5

Maintenance Management

Géza CS. NAGY

Maintenance and organisation

Financial support was provided by the DRIVEN project (Grant agreement No. 2020-1-SK01-KA203-078349) under Erasmus+ Call 2020 Round 1 KA2 - Cooperation for innovation and the exchange of good practices.


/Administration
/Human Resources
/Legal
/Accounting
/Finance
/Marketing
/Publicity
/Promotion
/Research
/Business
/Development
/Engineering
/Manufacturing
/Planning
789.51
971.91
279.82
555.74
818.71
536.85
43.67
ROBOT