

Influence of Maintenance Strategies on Environmental Load

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1 Depleting Natural Material Resources

The global resources are monotonously decreasing with the evolution of civilised life forms, so despite of the spreading of material-sparing design, the running out of energy providing materials is an ever increasing concern for mankind.

People use more and more raw material and energy produced from these materials to sustain and – driven by their nature – to continually develop the quality of their lives. This means increased exploitation of natural resources. In addition to the fact that this level is really high in developed societies, it increases dynamically in developing countries, owing to the greater population.

Contrarily, the volume of the exploitable global raw materials is decreasing. According to the opinion of optimistic research workers, taking into consideration the present consumption statistics and the estimated rate of increase, the depletion period of our most important minerals can be characterised as comparable to the order of magnitude of the lifetime of a generation.

The following aspects determine the uncertainty of the above-mentioned estimation:

- the number of the quarries – even excluding the depleting quarries – is growing, furthermore the research intensity depends on the needs;
- the declaration of some specific data may be intentionally distorted due to their strategic significance (*e.g. data presented by China, some of the Arabic countries or the Former Soviet Union*);
- the utilized quantity of some specific kind of minerals may decrease by changing or increasing the efficiency of the technology (*e.g. lead and some of the metals are being replaced by the wide range of polymers*);
- in some technologies utilization will be more sparing owing to the growing rate of recycling;

- alternative resources are also applied for energy production at a rapidly increasing rate;
- in addition to their significant role in the energy production, petroleum and natural gas are – for the time being – the fundamental raw materials of organic polymer technology.

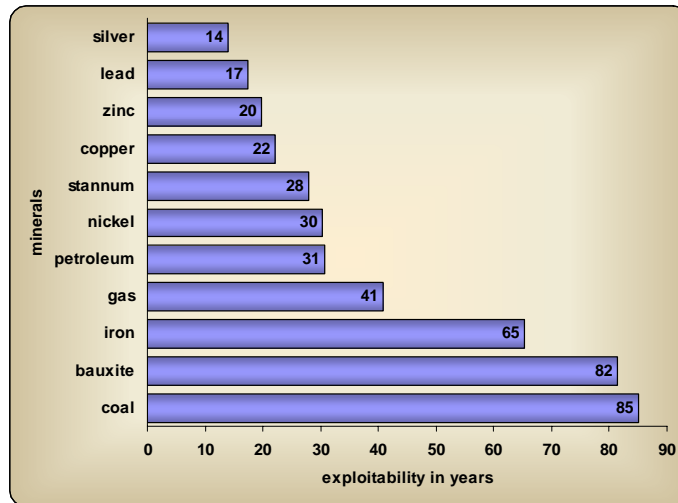


Figure 1

Estimated reserves of global mineral resources

However, it is generally admitted that the technological development demands bigger amount and more difficult machinery and electrical equipment, the production and annihilation of which also need raw materials. These are decreasing-depleting at various rates.

The manufactured consumer's goods are serving both our life and intellectual completion, so the subsistence of civilisation. The number of articles for use that we think „essential” is increasing and it generates the multiplication of the machinery and manufacturing systems producing them. Up-to-date „environment conscious” principles and technologies have been developed for the conditions to produce and annihilate them. Although the growth of environmental load due to the growth of volume is demonstrable, fortunately products of the modern age use energy more efficiently and require less valuable and recyclable raw materials. The aim of this lecture is to involve the audience and readers in our colloquy in the field of energy- and raw material consumption and environmental load.

2 Environment Consciousness regarding the Life Cycle of Products

The effect of the life cycle of the products on the environmental load is a point of interest in both the design, the fabrication, the operation and the waste treatment or reuse phase, and the applied solutions are considerably effective. Elaboration of the optimal variant regarding the environment begins already in the *design phase*, computerised virtual tests are utilised wherever possible. Processes of the *manufacturing technologies* are optimised for low need of resources and low exhaust of harmful substances; the highest possible percentage of wastes is recycled. During *operation*, when the product serves to meet our needs, the main target is the lowest possible energy need and material consumption, whether it is a washing machine, an industrial refrigerator or the turbines of an aircraft. It is a more and more widespread practice, that those products, which become useless at the end of their life cycles, should be made mostly of such kind of materials, which can be recycled or combusted in a waste incinerator, or at least will be rapidly degrade into harmless, low molecular weight substances in the dumping ground.

For the further discussion we have to distinguish between two functionally different segments of the operation phase, essentially two categories, i.e. the stages of productive and unproductive operation.

- Operation of the device during its useful life serves to meet the demands, this is the **stage of productive operation**. During this stage the hairdryer blows warm air, the printing machine prints newspapers, the car transports people and goods between two geographic points. All this is performed in a manner, designed in a more and more environment conscious way.
- Safe operation, however, renders maintenance of the devices necessary. This is defined as the **stage of unproductive operation** within the operation period of the life cycle. Risks of the consequences of spontaneous errors during this stage are assessed to an increasing degree (FMEA etc.). Main emphasis is laid not so much on the assessment of the burden or damages to the environment, as of the risk of accidents and operational safety. In the case of scheduled maintenance, on the other hand, the aim in the first place is the reduction to the minimum of the time needed to putting the device again into operation (mean time to recovery, MTTR) and of the involved costs.

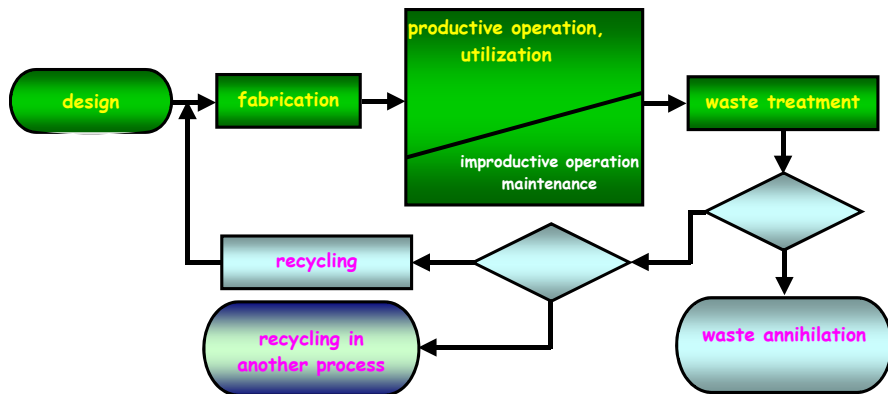


Figure 2

General life cycle of a product and stages of the „caretaking”

In the *unproductive operation stages* that we studied, however, no unanimous evidence could be observed of a positive development concerning the need of natural resources in the corrective and maintenance activities. A full assessment of the environmental impact is not considered to be of primary importance during the design/development of product and technology. The unproductive reservation executed according to the used maintenance strategies surely loads the environment in some form. The well-chosen strategy can fundamentally influence the level of this load (particularly in the case of equipments designed for longer life). The following should serve as thought-provoking examples regarding the strategies mentioned in the third chapter.

Considering the *appearance of spontaneous failures* from harmless breakdowns to havaries of catastrophic outcomes, we should think of the consequences and the effects to the environment. (Breakdown of an air conditioner in an office shall be deemed harmless, despite all the inconveniences observed, while a breakage of the shaft of the circulating pump in a chemical reactor or the breakdown of fuel supply in the engines of an airplane may have catastrophic consequences.) A simple failure itself, as well as the prevention of catastrophes or the handling of damages will consume resources and produce waste and pollution. Good examples are the effective protective packaging of spare parts or the diesel oil used up and combusted during polluted soil regeneration as well as accompanying environmental loads.

In some cases prevention may cause less load to the environment. In the case of processes and machinery having a slight environmental risk, replacement of the still operable component might be an economically better solution.

Nevertheless, from the environmental aspect it would be more advantageous to use it until the end of its life.

As part of *preventive treatments* machines are cleaned periodically, which can lead to production of harmful substances even in the case of simple mechanical cleaning (dusting, wiping), and the use of solvents can produce garbage even more harmful to the environment. The amount of replacement parts or lubricants, their packaging materials, pollution due to their transport, wastes during installation and putting into operation are all factors, which may determine the feasibility of the prevention strategy of a certain machine concerning aspects of environmental load.

In the case of fixed-cycle maintenance the more punctual estimation of the point of failure is exceptionally important, so as to throw away less operational reserves, from the aspect of environmental load.

In the case of the condition-based maintenance the above-mentioned point of failure is more predictable in order to prevent effects, which are caused by the sudden failure and shutdown and are influencing the environment. At the same time, the production, operation, continual replacement (owing to their rapid development) and maintenance of the machinery, which has been created to diagnostic purposes, emerges as a new element among the factors causing environmental load.

The more complicated the device itself is, the more resource-intensive are the maintenance processes and procedures, and the more environmental load they produce. As follows from the above, environmental load associated with the unproductive stage is a function of the state of the device, the maintenance needs and of the planned lifetime. When analysing environmental load during the utilization cycle of a product or facilities we should consider material and energy inputs and outputs both in the productive and in the unproductive categories.

Environmental aspects of the *productive area* are thoroughly investigated as a general practice when choosing among investment options. Generally they are closely linked with efficiency and standard requirements, in some cases directives apply for the allowable loads.

Economic aspects of the *unproductive activities* are also well known to decision makers, as the expenses of maintenance and upkeep are essential points. Other aspects of environmental load are, however, not always of economic nature. They play, therefore a subdued role in decision making, although the neglected environmental effects cumulated during long lifetimes may cause considerable differences.

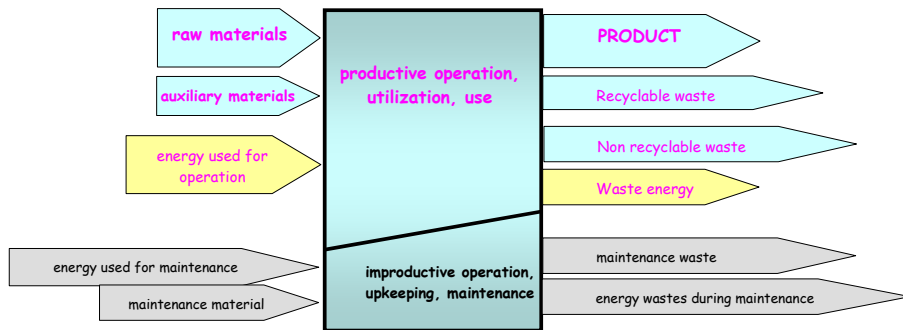


Figure 3

Simplified material and energy flow during utilization cycle of the product

3 Strategic Questions of Maintenance

Maintenance, which ensures proper operation and preserves value, forms part of the consumption phase regarding facilities and consumer durables.

In some decades' time maintenance was *problem-oriented* – eliminating problems was the basic target. Recently this has been replaced by the *process-oriented* maintenance strategy, depending on the field of application. Prevention has become the main objective. Using the human experience efficiently, today's technologies established the knowledge-based maintenance.

Event-based (repair in case of a defect, operative), *time-based* (inflexible periods) and *condition-based* (CBM) maintenance have been deeply analysed. Besides reliability and safety economic aspects should be taken into consideration while choosing the right approach.

Economical or safety risk, which has been undertaken consciously, may require machine replacement instead of service or maintenance in a specific case. This may be reasonable in case of especially rapid development.

The extreme rapid development can increasingly stress the environment all by itself: obsolescent machineries have to be annihilated or 'pushed' towards lower advanced appliers, where further exchanges would be generated. However, these replaced machineries were 'active'; their material and construction haven't reached the end of their duration of life.

Buying a new product is often induced by the deliberately high price of the components – it is generally known that a car would be much expensive if we bought it piece-by-piece.

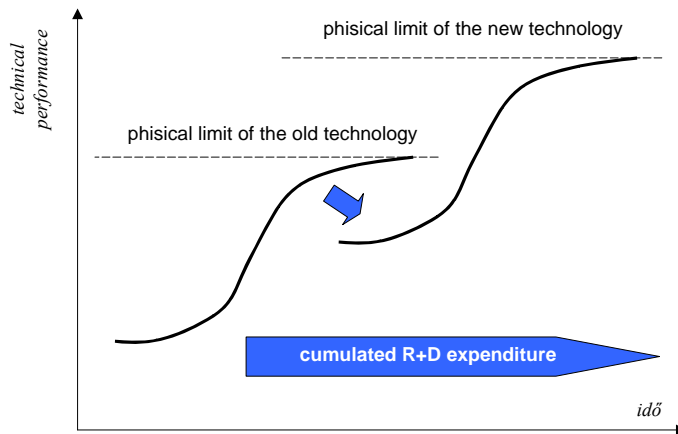


Figure 4
Model of changing technologies

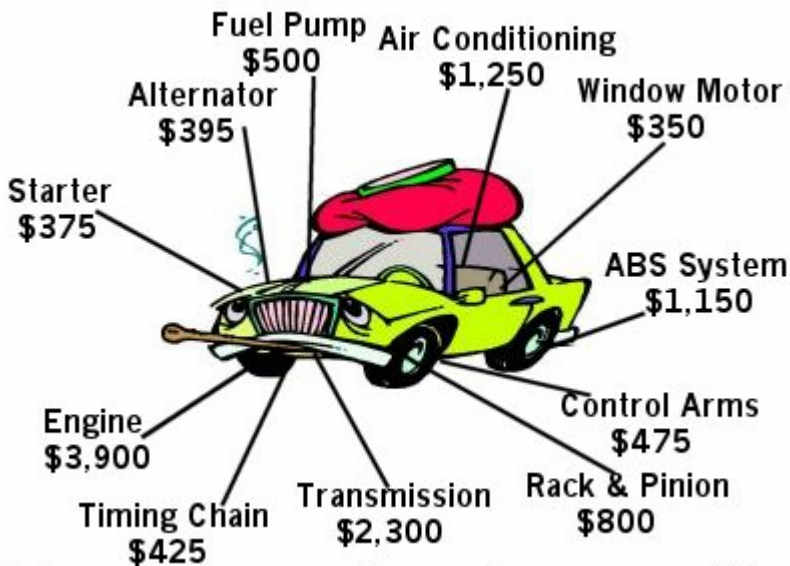


Figure 5
Disproportionate prices of the components

The development of diagnostic procedures has been generated primarily by condition-based maintenance. From the methods originating from the human therapy to the knowledge-based professional systems numerous procedure facilitated the trace-back and forward analysing techniques. The passively *reacting* maintenance has been replaced by the *active*, forecasting and the *proactive* maintenance, which uses real-time data.

In the case of consumer durables – e.g. cars –, the on-line supervision appeared besides the periodical status-check. Built-in sensors and indicators make more efficient the active and passive diagnostic procedures.

The *Total Production Maintenance* (TPM), known as a maintenance-organization method, is based also on the human factor.

In case of big-sized, primarily technological complex systems, initial strategies would have ensured the high level of availability and safety by quite high expenditure. In order to meet technical demands *reliability-centred* maintenance has been developed (RCM). By the analyses of the effect on the technological and social environment, their probability and severity, the next step was the *risk-based* maintenance (RBM).

The *Risk Based Inspection and Maintenance* (RBIM), which synthesizes the former maintenance elements, is spreading through Europe. Its RBI analysing element, which is based on diagnostic possibilities, filters out the factors of high risk by qualitative analysis, determines their risk, and generates a risk matrix and a hierarchy. Of course the final target is to choose the optimal maintenance strategy and to develop an inspection/maintenance program on this basis.

The above-mentioned strategies and philosophies can be applied just partially regarding consumer durables and facilities. The contradiction between the value-preservation demand and the new product promotions is typical of the consumers' society. In our age sometimes the life cycle of facilities of the traditionally long rate of return (e.g. buildings) become very short. However, despite the rapidly accelerating period of reproduction, the economy and environment-friendliness of the unproductive operational phase of the consumption period is determined by the applicable maintenance strategy and therefore basically by the product construction.

4 Responsibility of the Developers

The complex organization of design and development consist of engineers and marketing professionals. They have increased responsibility to develop environmental-conscious products to fulfil social needs and to generate environmental-conscious demands in the society, which is present in their entire life cycle.

After the detailed analysis of the consuming phase of life cycle and the discussion about the special aspects of the related maintenance strategies here you can find some thesis regarding consumer durables and facilities:

- The consumption and operational period of the complicated and expensive products and facilities may be quite long. As a result, the environmental load of the reservation and maintenance activities would also be remarkable. In

other words, even more emphasis is put on environment-conscious operation in the case of equipments designed for longer life in productive as well as unproductive fields.

- The level of environmental consciousness depends also on the advancement of the given society. In a technologically developed country people think more “green”, therefore a kind of environmental culture is able to develop that will be able to pay particular attention to the unproductive period regardless of money or time.
- Nations aiming to fall into line focus on design and manufacture in order to meet the strict requirements of the “big ones”. They don’t have the possibility to decrease the ecological effects of the unproductive maintenance activities.
- In general, the degree of the environmental load concerning the consumption period infiltrates into the product at the design phase. During the operation just a slight modification can be done to these eco-parameters.
- Our articles for use that ensure better quality of life are getting more and more complicated, those are embossed with safety, information and comfort elements. These are generated by the overdriven technological development of the leader manufacturers and by the “pumped up” customer needs.

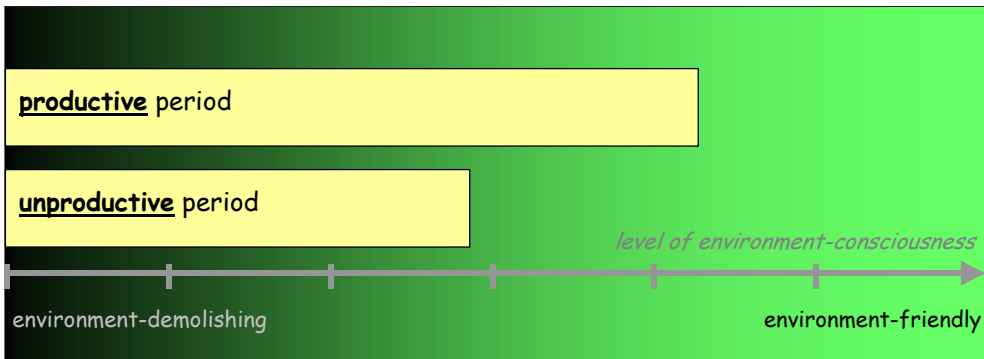


Figure 6

General advancement of the environmental consciousness in two periods of the operational phase of the life cycle

The main objective of this lecture is to drive the attention to the fact that although reservation and maintenance are small segments of the impacts causing global warming and resource depleting, the operation of our society is basically determined by the operation and reservation of our facilities and consumer durables. As a result, our creativity plays a significant role in our own and our grandchild’s life. If taking care of the environmental load of unproductive operational periods means value for the society and the operators, this demand would reach the designers and spread towards the less conscious consumers.