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New Trends in a Vehicle Maintenance System

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Abstract:

In this article the author describes particular maintenance systems used in the past, some of which are used also at present. The basic maintenance systems include maintenance after use, preventive maintenance with predetermined intervals, and conditioned-based preventive maintenance - predictive maintenance. These maintenance systems were continuously improved and new ones were added – so called computerized maintenance management system, reliability centred maintenance, and total productive maintenance. The article further describes new methods of performing the maintenance based on proactive maintenance with using telemaintenance, which may be simply explained as remote-controlled maintenance.

Keywords:

Telemaintenance, maintenance, corrective maintenance, preventive maintenance, predictive maintenance, computerized maintenance management system, reliability centred maintenance, proactive maintenance.

1. Introduction

Quality and reliability control and the choice of optimal maintenance methods cannot be realised at present without properly functioning technical diagnostics. Thanks to the use of technical diagnostics, the maintenance itself has reached a new level which in a sense may be labelled as a completely new, generation different maintenance system.

Technical literature provides a number of definitions of "maintenance", more or less influenced by their authors or by the force of a norm upon which they are based. For the purpose of this article, the following definition according to [1] is used: "Maintenance is a combination of all technical, administrative, and managerial activities during a life cycle of an item aimed at maintaining the item in condition, or returning it to condition, in which it can perform a required function."

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2. Development of Maintenance Approaches

A vehicle is either in usable or unusable condition. Our aim is to maintain the vehicle in usable condition, which means to prevent its failures and limiting condition. This aim should be achieved upon the lowest vehicle life cycle costs possible while keeping inherent reliability of the vehicle for the whole operating time. This has been manifested in particular maintenance systems since the 1930's until the present, which is shown in Fig. 1. In general, maintenance system approaches may be divided as follows:

1. Corrective maintenance system.
2. Preventive maintenance system – schedule based.
3. Preventive maintenance system – condition based:
   a) predictive maintenance system,
   b) proactive maintenance system.

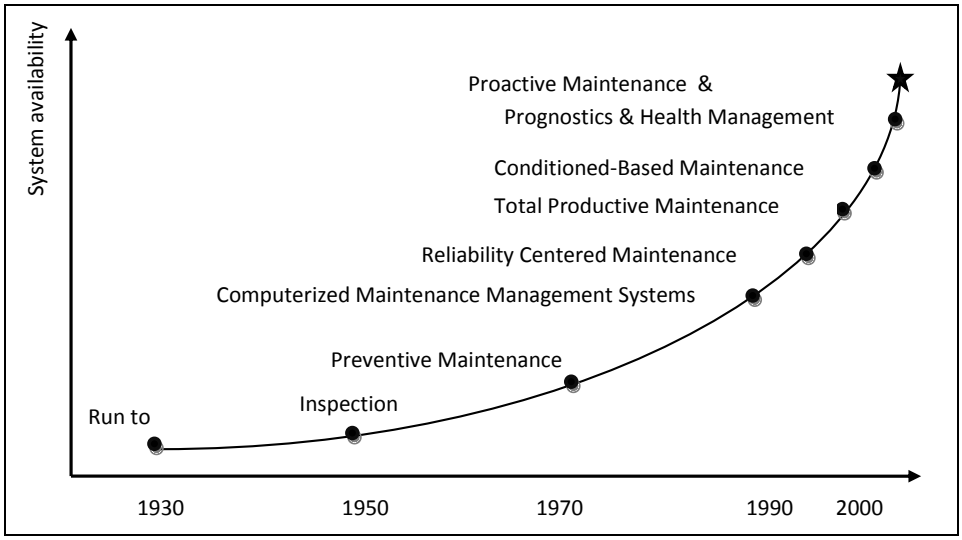

Fig. 1 Development of maintenance approaches since the 1930's

2.1. Corrective Maintenance System

This maintenance system represents the lowest level of the maintenance approach. It is the maintenance performed after failure condition has been detected and it is aimed at bringing the item to the condition in which it can perform required functions of the given equipment. In practice this means that the equipment is operated without supervision for its whole durability and maintenance is performed only when a failure occurs. In this case repair costs are high, including loss due to the vehicle being out of operation.

Corrective maintenance (1st generation maintenance) may be applied to simple and cheap machinery in which 100% backup and prompt repair or replacement can be provided. This type of maintenance is obviously suitable only in these cases:

- The broken part may not be repaired or is not worth repairing.
- The machinery is cheap compared to maintenance costs.

- The part replacement is very fast, technically feasible and economically acceptable.
- No other maintenance method is possible to be performed.

In later years, corrective maintenance started to be completed with so-called *Inspection*, the aim of which is to verify the compliance by measuring, monitoring, checking or comparing significant characteristics of the vehicle performed during the primary failure removal.

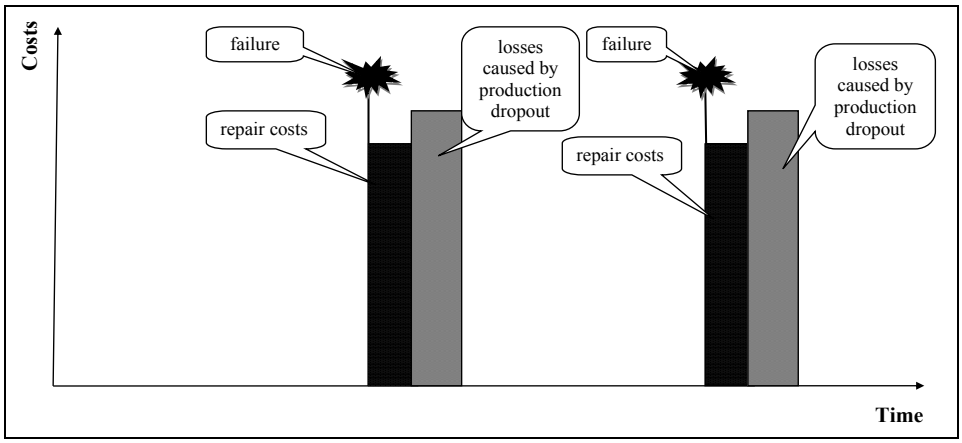

Fig. 1 Cost diagram of corrective maintenance [2]

2.2. Preventive Maintenance System with Predetermined Interval

This system is still frequently used since in principle it comes from the theory of reliability. Upon theoretical reliability and practical experience from a similar technique fixed time intervals are set for performing the "service maintenance" ("schedule-based maintenance"). Preventive maintenance is maintenance performed in predetermined intervals or according to specified criteria, and aimed at reducing the probability of failure or degradation of the item operation [1].

An advantage of this system is the prevention of failure and thus reduction of corrective maintenance costs. However, preventive maintenance costs will increase. The aim is to keep the maintenance costs as low as possible. In practice the total maintenance costs are relatively high, but in the overwhelming majority of cases they are lower than for "corrective maintenance", see Figs. 2 and 3. Another advantage is even distribution of costs in time, and the fact that costs incurred by a vehicle dropout are lower and mostly planned in advance.

A fundamental drawback of scheduled maintenance is the fact that the period (maintenance interval) is often shortened due to the reduction of failure risks and the action is performed on a vehicle which does not exhibit wear signs. Therefore maintenance costs increase and actions performed reduce planned durability of the vehicle. It is true that every useless dismounting and mounting of a part or assembly, or disassembling and assembling the whole vehicle, changes distribution of clearances and brings further unknown static and dynamic loads to the run-in vehicle. This leads to its increased wear and fatigue damage occurrence.

This maintenance system was gradually developed and completed in order to achieve maintenance costs reduction and keep inherent reliability of the vehicle. Higher efficiency was achieved by introducing so-called "*Computerized Maintenance Management System - CMMS*" which leads to significant improvement of the maintenance efficiency by making information on performing individual types of maintenance more available [2].

The schedule-based preventive maintenance system was further completed with so-called "*Reliability Centred Maintenance – RCM*". This method is based on a systematic approach for the identification of purposeful and effective tasks of preventive maintenance which are performed in compliance with a specific set of procedures for determining intervals between the maintenance tasks. The aim is to improve overall safety, availability, and efficiency of the operation. It is also based on monitoring the total vehicle life-cycle costs.

Further improvement of the schedule-based preventive maintenance system brings so called "*Total Productive Maintenance – TPM*". The performance of each organisation depends especially on work organisation, utilisation of basic equipment, and qualification level of its employees. To achieve maximal performance, the organisation must utilize optimally the vehicle productivity. In terms of losses, the vehicle maintenance represents a significant area where productivity should be increased and resources for cost reduction sought for. TPM utilizes abilities and skills of all employees with the aim to significantly reduce downtimes of vehicles and individual losses in their usage. On this account, organisations are strongly advised to use this progressive approach.

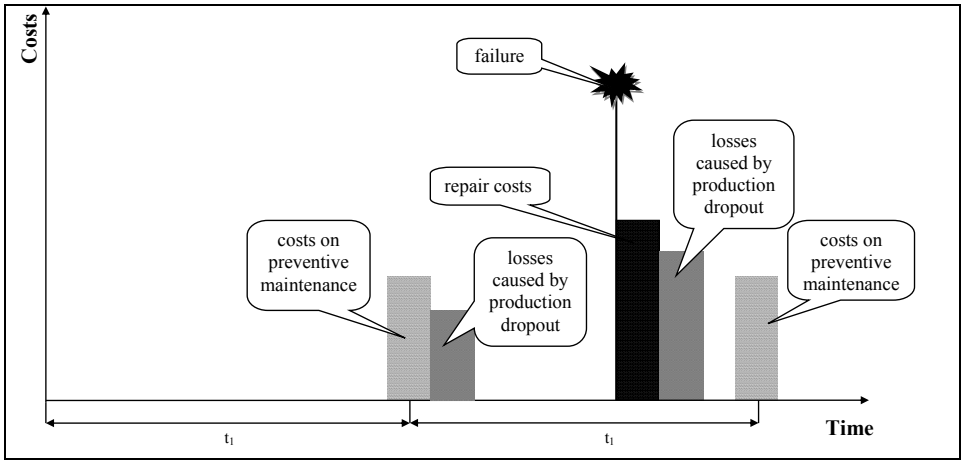

Fig. 2 Cost diagram of preventive maintenance system with predetermined interval

2.3. Preventive Maintenance System – Condition Based

Technical condition based maintenance was gaining importance in past decades with the expansion of technical diagnostics. It is preventive maintenance comprising of monitoring performance or parameters and of consequent measures [1]. Its main benefit resides in consistent removal of failures. Particular worn parts and parts or whole assemblies in the risk of failure are repaired or replaced optimally in advance.

Thus failure occurrence is prevented. This technical condition-based maintenance system may be divided to:

a) predictive maintenance,
b) proactive maintenance.

ad a) Predictive maintenance

This is condition-based maintenance performed upon a prediction derived from an analysis and evaluation of significant parameters of the item degradation [1]. An action is performed on the item only when it is technically and organisationally justified sufficiently enough to maximally exhaust technical durability of the critical part, and at the same time unexpected accident was prevented. In other words, this is maintenance based on a statement that only that defect is to be repaired on the item, which must be inevitably repaired and only when the repair is inevitable. The maintenance itself is based on periodical evaluation of technical condition. Maintenance mechanisms applied to the vehicle allow yielding information on the change of technical condition of monitored parts. Such information is processed with the aim to estimate remaining durability, and thus to commence the process of a technical action (remedy). For monitoring signs of developing damages "Condition Monitoring", usage of specialised instruments is required, designed for collecting and evaluating information. These instruments utilize so-called technical diagnosis. The equipment is to be monitored and evaluated constantly, or at least periodically.

Costs of the maintenance itself are several times lower than in the previous alternatives. The vehicle downtime for the time required for preventive maintenance is usually negligible in comparison with corrective maintenance. However, initial costs of purchasing the diagnostic systems are relatively high. Therefore it is necessary to consider whether these costs of purchasing the technical diagnostics instruments together with maintenance costs will or will not be higher than maintenance costs without using technical diagnostics.

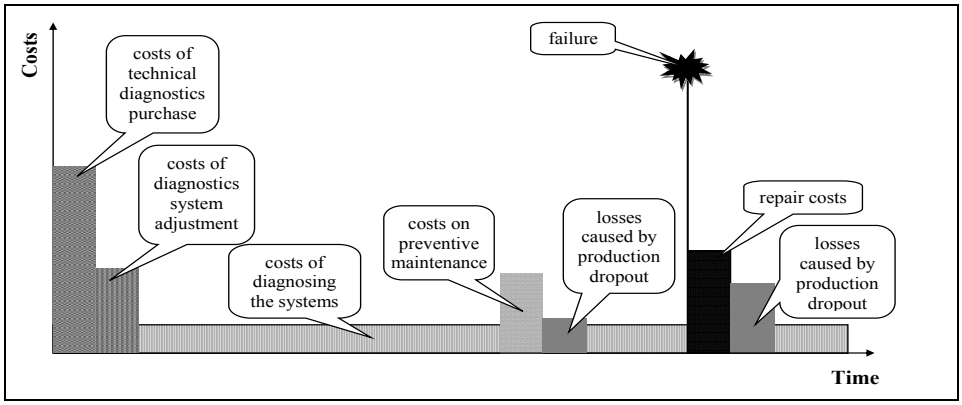

Fig. 3 Cost diagram of predictive maintenance system

ad b) Proactive maintenance

Proactive maintenance is considered another higher level of maintenance. It is completely based on the previous predictive maintenance which it further improves so

that its basis is the utilization of more complex technical diagnostics. Basically it is the top current version of predictive maintenance based upon actual condition of the item operated. It is analysed in detail in the following chapter.

3. New Trends in Maintenance Systems

One of the latest trends in maintenance systems is proactive maintenance completed with so-called "telemaintenance". The proactivity is manifested also in the fact that new vehicles are designed with respect to an easy access to their integral diagnostics. Possible connection of diagnostic systems, location of sensors and measuring spots for monitoring vibrations, temperatures, lubricant sampling and detection of other selected parameters should be considered during the vehicle design.

Proactive maintenance arose from the predictive maintenance type as a reaction especially to long-term findings that a certain group of failures repeats periodically upon clear causes. The causes include mainly the following:

- Incorrectly organised maintenance work.
- Incorrectly performed maintenance (technical operation in the vehicle).
- Unqualified operators and maintenance personnel.

The proactive maintenance type is aimed at keeping inherent reliability of the vehicle on an acceptable level. As a source of information technical diagnostics is utilized. The main objective of proactive maintenance is:

- Further reduction of maintenance and operational costs.
- Prevention of failure occurrence and thus extension of an interval to preventive maintenance, meaning extension of the vehicle durability.
- Statistic control of accidental and systematic influences affecting the vehicle operability.

Proactive approach means not only monitoring and evaluating the vehicle condition, but especially performing such actions that prevent or at least postpone damage occurrence. New aspects brought by proactive maintenance:

1) Emphasis laid on long-term stability of the vehicle technical condition. It is monitored with diagnostic signals and statistical methods of their processing. The objective is thus a complex reliability of the vehicle.
2) Consideration of the item technical condition with emphasis laid on future development. The future condition is forecast a longer time ahead and with more complex procession of diagnostic signals. Proactive maintenance lays stronger emphasis on the analysis of the failure causes and on activities which should prevent them in future.
3) Broad cooperation of all company sections related to the maintained item. An important aspect is strengthening the team in the work of which a broader spectrum of personnel responsible for the item activity participates. Proactive maintenance holds elements of a system scientific approach, to which employed methodical, metrological as well as software instruments must correspond.
4) Bigger interconnection of maintenance and production. Maintenance becomes another tool of the process statistical regulation. Technical condition variation is a source of the variation of qualitative indicators.
5) Qualitative broadening of predictive maintenance while utilizing its advances and information potential. In this respect it shares with predictive maintenance especially practical performance of individual activities.

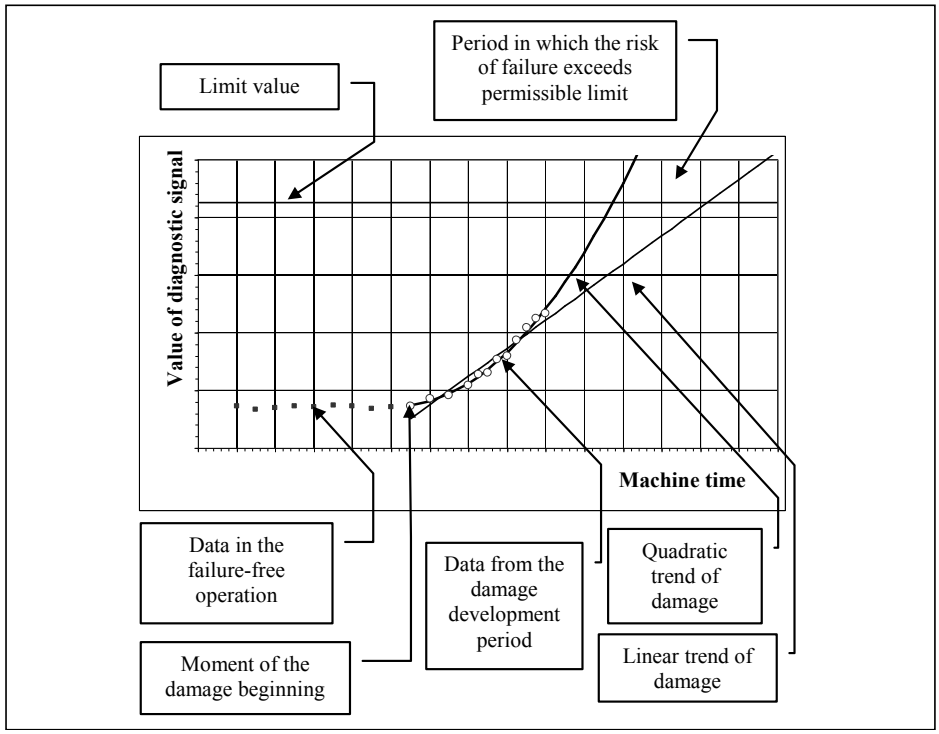

Fig. 4 Linear and quadratic trend of parts damaging

The employment of proactive maintenance significantly decreases costs of the introduction of diagnostic systems for periodic or constant monitoring of the vehicle operation. Thanks to this the proactive maintenance costs are lower than predictive maintenance costs. Utilisation of "on-board technical diagnostics" leads to the reduction of failure occurrences, which further leads to the reduction of maintenance costs. Further, time to a preventive action is extended and thanks to these indicators costs of losses incurred by vehicle downtimes are lower. Indeed, the vehicle purchase cost will increase. Therefore the main criterion is the total costs of the vehicle life cycle which should be lower.

The latest trend in the maintenance area is so called "telemaintenance", which may be explained as remote-controlled maintenance employing the proactive maintenance principle. In some publications, the term "Remote Diagnostics & Maintenance (RD&M)" is used [4]. It is based on wireless transmission of technical data about the vehicle. The main field of its utilization is in companies specializing in long-distance transportation and also in military environment. This method enables on-line monitoring of parameters upon sensors integrated in the vehicle and wireless transmission of the information to a remote computer. This is utilized especially for securing missions in a foreign territory.

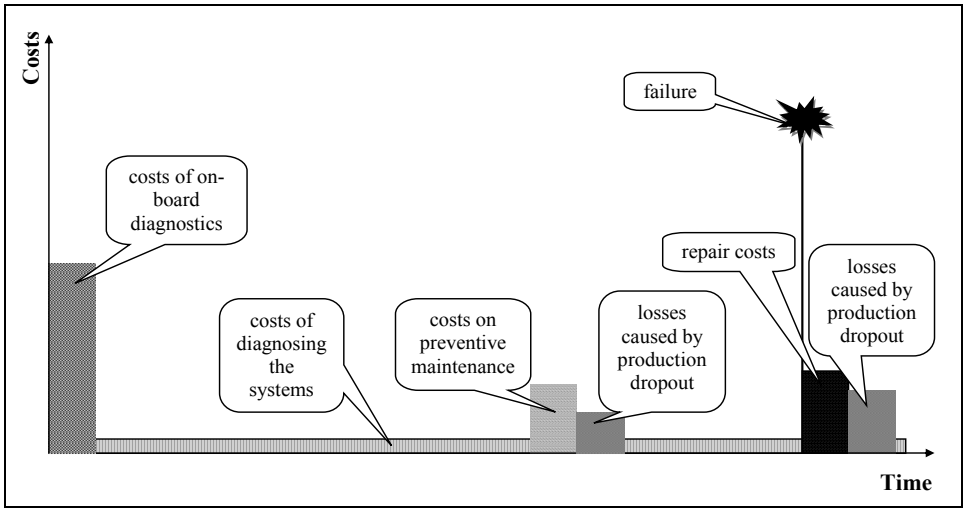

Fig. 5 Cost diagram of the proactive maintenance system

Telemaintenance may be divided to the following four levels:

1. Diagnosed vehicle with a driver.
2. Support logistics centre where a computer processing the diagnostic information is located.
3. Experts performing the maintenance on the vehicle.
4. Vehicle manufacturer who supplies a technical database including drawings and technological procedures for maintenance.

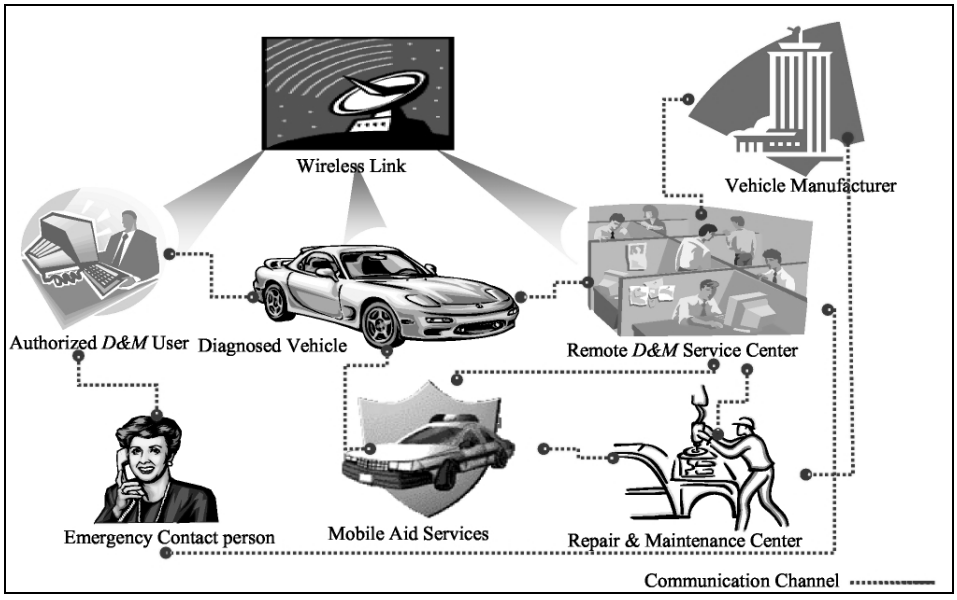

Fig. 6 Telemaintenance system diagram [4]

Fig. 7 shows a schematic telemaintenance system based on wireless transmission of diagnosed data from the vehicle to the telemaintenance logistics centre and to the vehicle user. The vehicle electronic control unit makes performance indicators and error codes accessible for an analysis; these are sent to the logistics centre. Here, in case of error messages an advisor informs the driver about the problem severity and advises on the possible problem removal or provides necessary service support. It means the advisor ensures the vehicle maintenance or repair in place with the use of a mobile emergency service, or arranges maintenance in the maintenance and repair centre. If necessary, the logistics centre further communicates with the vehicle manufacturer who supplies the centre with new data materials for particular vehicle types.

4. Conclusion

The purpose of this article is to introduce the development of particular maintenance approaches since the beginning of the 20th century to the present. It includes advantages and disadvantages of performing maintenance after use, preventive maintenance with predetermined interval, predictive maintenance and proactive maintenance. Further the article presents diagrams showing costs spent on preventive maintenance, corrective maintenance, losses caused by the vehicle dropout, and costs of diagnostics. The final part brings a new approach to maintenance based on on-board diagnostics, which is on-line testing of diagnostic signals and their wireless transmission to the telemaintenance logistics centre.

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Acknowledgement

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