DETERMINATION OF VEHICLE DURABILITY TIME BASED ON LIFE CYCLE COSTS AND FAILURE INTENSITY

ОПРЕДЕЛЕНИЕ ПЕРИОДА РЕСУРСА ТРАНСПОРТНОГО СРЕДСТВА НА ОСНОВЕ ЗАТРАТ ЖИЗНЕННОГО ЦИКЛА И ПАРАМЕТРА ПОТОКА ОТКАЗОВ

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Abstract:
The paper deals with the determination of optimal vehicle durability time depending on life cycle costs and failure intensity. This method adopts two separate approaches. The first approach is based on the life cycle costs calculation, and the second on the determination of failure intensity relation. As an example of vehicle durability time assessment, the monitoring and calculation of the fixed indicators of the Land Rover Defender is used. In the course of twelve years 55 Land Rover vehicles were monitored. These vehicles drove almost eight million kilometres.
KEYWORDS: VEHICLE DURABILITY TIME, VEHICLE LIFE CYCLE COSTS, FAILURE INTENSITY.

1. Introduction

The initial programme of the vehicle maintenance is often elaborated in cooperation between a supplier and a user, and is prepared before the vehicle is put into operation. However, this maintenance programme is not always optimal. Therefore, immediately after the commencement of operation it is very useful, to initiate data collection on the actual course of degradation and failure occurrence, including the cost demands, i. e. to create a dynamic maintenance programme. This programme makes possible to calculate the life cycle cost (LCC) and failure intensity, which can be used for the assessment of the vehicle durability life assuming that the recommended reliability is kept.

The primary guidance for vehicle life cycle cost evaluation is a standard. According to this standard the vehicle life cycle cost can be divided into these six periods:

- concept and demand determination period,
- design and development period,
- manufacture period,
- installation period,
- operating state and maintenance period,
- liquidation period.

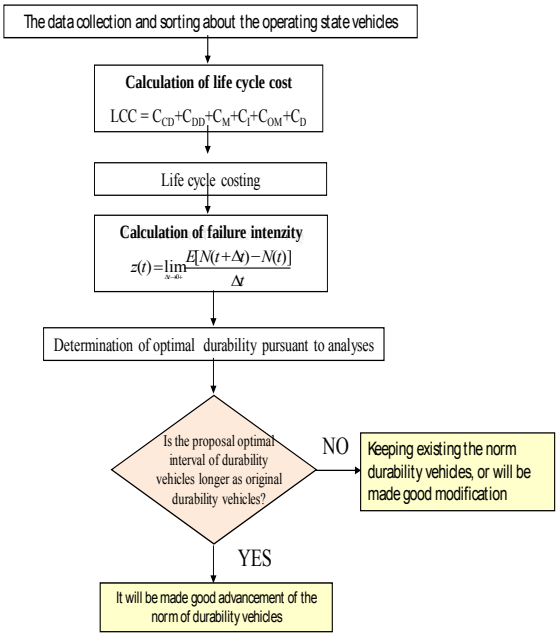
Generally, the total costs incurred in the abovementioned stages can be divided into:

1. purchase costs,
2. proprietary costs,
3. liquidation costs.

2. Model design for vehicle durability time determination depending on life cycle costs and failure intensity

For the optimal mean time determination of the vehicle durability time it is necessary [1]

1. to carry out the calculation of vehicle life cycle cost; for this purpose it is necessary to be familiar with
   - the purchase costs of the vehicle and its amortization,
   - costs on operating state,
   - vehicle maintenance costs,
     - corrective maintenance costs,
     - preventive maintenance costs,
   - liquidation costs.
2. to carry out failure intensity calculation.
3. to determine the vehicle mean time on the basis of the curve course of the vehicle life cycle cost and the curve course of failure intensity, so called vehicle durability.



Graph 1: Model for the determination of vehicle durability

3. Vehicle durability time determination depending on vehicle life cycle cost

3.1 Costs on vehicle purchase and its amortization

a) Costs on vehicle purchase

The vehicle purchase cost can be expressed by the following equation:

$$C_{PC} = C_{CD} + C_{DD} + C_M + C_S + C_{RG} \qquad (1)$$

where: C_{CD} - costs on concept and demand determination period,
C_{DD} - costs on vehicle proposal and development period,
C_M - costs on manufacture period,
C_S - costs on vehicle sale period,
C_{RG} - costs on repair during guarantee period.

In this case the purchase cost for the basic version of the Land Rover Defender was set at 830000 CZK in 1995.

b) Vehicle amortization calculation

Basic amortization (BA) is calculated as the arithmetic mean of a percent reduction for operating state time (A_{OT}) and percent

reduction for a number of kilometres (A_{NK}) according to amortization scale [3].

$$BA = (A_{OT} + A_{NK})/2 \qquad (2)$$

3.2 Costs on vehicle maintenance

a) Costs on corrective vehicle maintenance

The total cost amount necessary to expend on vehicle repairs during its operating state depends apparently on the number of failures which occur in the vehicle during its usage, and on the cost amount necessary to remove each failure. If the failure rate λ is regarded as a measure of reliability level, it is possible to use the following equation for repair support costs:

$$C_{OMC} = \lambda\, t\, \hat{c}_R, \qquad (3)$$

where: C_{OMC} - costs on repairs during operating time t,
λ - failure rate,
t - operating time,
$\hat{c}_R$ - average price of the vehicle, whereas it is estimated that this price is again dependent on the vehicle reliability level, i. e. on failure rate.

b) Costs on vehicle preventive maintenance

The costs include the scheduled costs of the maintenance which is done in accordance with the determined time plan for vehicle maintenance.

Total costs amount which will be necessary to spend on preventive maintenance during operating state apparently depends on the number of preventive maintenance actions which are necessary to be done on the object during its usage, and on the costs amount necessary to carry out these preventive maintenance actions. For the costs on preventive maintenance the following equation can be used:

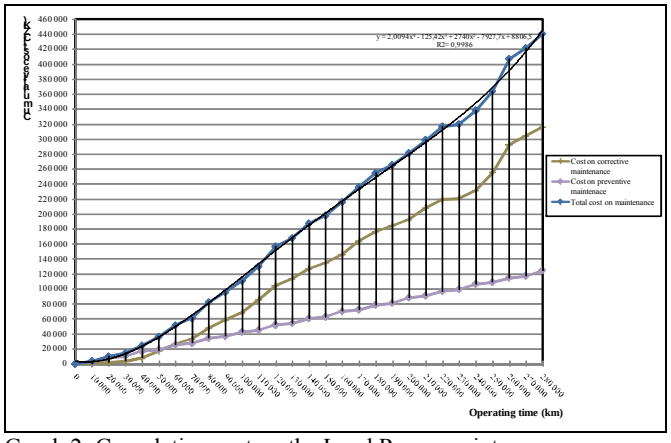
$$C_{OMP} = t\, \hat{c}_M, \qquad (4)$$

where: C_{OMP} - costs on preventive maintenance during operating time t,
t - operating time,
$\hat{c}_M$ - average costs on preventive maintenance applied to an operating time unit assuming that these costs are again dependent on the vehicle reliability level, i. e. on failure rate.

c) Total costs on vehicle maintenance

The total costs on vehicle maintenance consist of preventive and corrective maintenance.

$$C_{OM} = C_{OMC} + C_{OMP} \qquad (5)$$



Graph 2: Cumulative cost on the Land Rover maintenance

3.3 Costs on operating stage

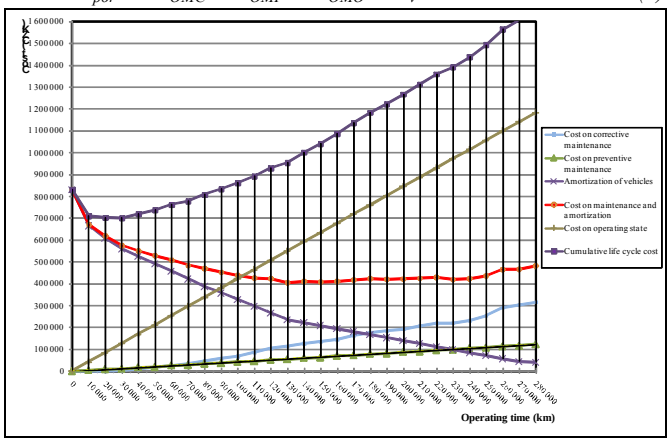
The operation stage costs include the fuel cost $\mathbf{C_F}$, working fluid costs, oil and motor lubricant costs $\mathbf{C_{FOL}}$ - these are refilled during vehicle operation (not during the maintenance stage), tyres cost $\mathbf{C_T}$, accumulator battery cost $\mathbf{C_{AB}}$, motor vehicle insurance cost, road traffic tax cost, and/or further cost resulting from law $\mathbf{C_{ITF}}$, motorway toll cost $\mathbf{C_{MT}}$, technical check cost $\mathbf{C_{TC}}$, exhaust-emission measurement cost $\mathbf{C_{EM}}$ and continuous education and training cost $\mathbf{C_{ET}}$ [2].

$$C_{OMO} = C_F + C_{FOL} + C_T + C_{AB} + C_{ITF} + C_{MT} + C_{TC} + C_{EM} + C_{ET} \qquad (6)$$

3.4 Vehicle life cycle costs

The total costs on vehicle operating state consist of the purchase costs of the vehicle and its amortization, corrective maintenance costs and preventive maintenance costs, and costs on operation state and liquidation.

$$LCC = C_{por} + C_{OMC} + C_{OMP} + C_{OMO} + C_v \qquad (7)$$



Graph 3: Example of the Land Rover life cycle cost

Graph 3 shows that until the run up to 130000 km, the vehicle maintenance and amortization costs tend to decrease. After that the curve shows constant course and its value is around 410000 CZK. This trend continues up to the 250000 km run, and then the maintenance and amortization costs begin to increase. Therefore, in line with general knowledge of the reparable objects life cycle costs curve, I recommend the Land Rover durability time should be 250000 km.

4. Vehicle durability determination depending on failure intensity

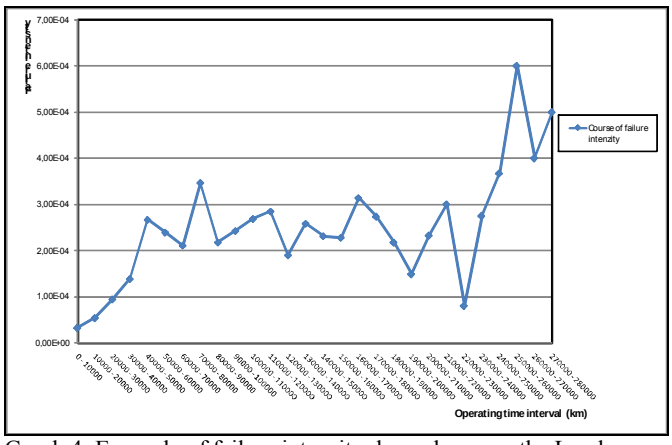
Failure intensity z(t) is the limit, if this exists, of the ratio of the mean number of failures of a repaired item in a time interval (t, t+Δt), and the length of this interval, Δt, when the length of the time interval tends to zero [4].

$$z(t) = \lim_{\Delta t \to 0+} \frac{E[N(t+\Delta t) - N(t)]}{\Delta t} \qquad (8)$$

where: $N_{(t)}$ - is the number of failures in the interval (0, t),
E - denotes the expectation,
$t + \Delta t$ - the time interval.

Generally we can divide failure intensity into three different stages:

- in the first stage of failure intensity there is a steep grow,
- in the second stage failure intensity oscillates around a constant value. The probability of failure occurrence in a random moment is practically the same. Periodical oscillation *z(t)* is caused by periodical maintenance,
- in the third stage there is a rapid grow in failure intensity and further usage of the vehicle becomes uneconomic, and therefore it is necessary to consider vehicle liquidation or to carry out so called overhaul.



Graph 4: Example of failure intensity dependence on the Land Rover operating time

These general demands, which have been specified, fully occurred in the Land Rover failure intensity calculation.

Graph 4 shows the Land Rover failure intensity curve. As it follows from the curve course, the failure intensity increases up to the 50000 km run. After this point, until the 250000 km run the curve shows constant course. Then there is a sharp increase in the failure intensity value, which indicates a growth in failure occurrences. Therefore, this point can be considered as the crucial point for the vehicle durability time determination, or for vehicle overhaul.

5. Conclusion

The article describes two possible approaches to the determination of optimal vehicle durability time. To carry out this task successfully, it is necessary to collect and sort data on the occurrence and relevancy of failures, costs on failures removal, preventative maintenance costs and costs on operating state. The article shows two separate approaches to the determination of vehicle durability time. The first solution is based on the vehicle life cycle cost calculation. In the second case, the failure intensity calculation has been used. In this case, the vehicle durability time for the Land Rover Defender was calculated at 250000 km. This results from the calculation using both abovementioned independent methods.

6. References

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