VERIFICATION OF TRIBOLOGICAL METHODS FOR AUTOMOBILE PARK OPERATING ABILITY EVALUATION IN SYRIAN ARAB REPUBLIC

HEKMAT AL HAKIM, ČORNÝ I.

Abstract

Lubrication of different vehicle parts is an economic as well as a technical problem that is decisive concerning reliability of various equipments, especially motorised ones. Broad range of diagnostic methods can be implemented to test the technical state of machinery parts - engine, transmissions, etc. If implemented right, these methods can save money by reducing costs generated during different stages of vehicles' service life. The costs can be due to the premature wear-out, break-down or irrelevant maintenance, etc. (AL HAKIM)[1-3]. The problem is very complex and many surveys, tests, and experiments have been done to answer the question: Is the machinery part (or machine itself) still economically operable?
This, the main focus of the article is on lubrication problems in vehicles that are subject to harsh operating conditions in Syrian desert roads. Tribological diagnostic methods are offered for monitoring the vehicles as a mean to improve the technical state of the vehicles.

Key words: lubrication – oil diagnostics – service life – tribology – engine wear - reliability

INTRODUCTION

Since first complex machines (including motor vehicles) appeared, it became clear that the friction between many machine parts is the main cause of energy loss and parts` wear. The tribology emerged as a science focused on solving these problems. Modern tribology offers comprehensive range of methods to assess the state of lubricants (oils, greases, even solid lubricants), to evaluate process of engine wear, to determine oil change period, etc.

Literature analysis and theoretical consideration

The machinery parts wear in tribological systems is defined as a quantified parameter. It can be represented as a volume or mass of material displaced from friction contact surfaces (this can be simply determined by weighing). However, the most eloquent definition of wear is represented by the thickness of displaced layer (ŠTĚPINA)[6]. By implementing wear particles separator apparatus, the article shows that with increasing wear regime, number and size of wear paricles in implemented oil increase according to following formulas (AL HAKIM)[2,3]:

$$WPC = \frac{D_L + D_S}{1800} \cdot 100 \quad [\%]$$

$$PLP = \frac{D_L \cdot k}{D_L + D_S} \cdot 100 \quad [\%]$$

where *WPC* is wear paricles concentration, it is a static characteristic; *PLP* is percentage of large particles (wear intensity), *PLP* represents dynamic characteristic; D_L is concentration of large wear particles; D_S is concentration of small wear particles; 1800 is a constant representing apparatus measuring range; *k* is a coefficient, *k* ranges from 0.01 to 0.9.

State-of-the-art tribological methods for the automobile park operating ability evaluation

The methodology of experimental activities and their assessment was used as described in reference 2 (HAKIM 2000).
It is nes¨cessary to say that tribology as an inter-disciplinary science applies various methods to investigate tribological processes. Essential task in tribology dwells not in observation methods but in interpretation of obtained results and in applying of these results (HAVRLAND - SRNEC - AL HAKIM)[5].
The list of the methods should give a picture of how broad and heterogenous the range of the methods is:

- Neutralization number
- Saponification number
- Total base number (TNB)
- Tarnish and solidification point
- Flash and burning point
- Water content (xylol method)
- Ageing resistance
- Total contamination (matters insoluble in benzine)
- Solid extraneous matters (matters insoluble in benzene)
- Ash content
- Bitumen content
- Atomic absorption spectroscopy
- Atomic emission spectroscopy
- Colourimetric method (RAMO)
- Inductive method (ferrography)
- Ferrodensitometry

- Chemical analysis of oil centrifugal cleaner sediments
- Chromatographic paper drop test
- Mathematical method.

Experimental observing of the automobile park

It is apparent that a single method can not provide sufficient results for a complex assessment of machine operating ability since each method is focused on a different aspect of machine operating regime. It is necessary to carry out several methods that would provide a base for conclusions and prognosis. In this case five methods were chosen as dominant:

- Flash point
- Water content
- Ferrography
- Total contamination
- Mathematical method.

Flash point

The flash point is a state described as follows: a sample of inflammable liquid is heated (according to specified conditions in special apparatus) to evaporate such amount of vapours that the mixture of the vapours and air above liquid surface will burn for a short while after approach of testing flame. The result is given in ºC.

Water content

The method using apparatus CTT INFRA (manufacture by Coop. Modletice) is subjective (requires certain experience from the researcher). The water content is determined acoording to the number and intensity of water vapour bubbles creation.

Ferrography

Ferrography is a technique enabling separation of metal particles (mostly of magnetic metals) from operating lubricant. Evaluation is realised with microscope. Ferrography allows determining category and kind of wear, sort and origin of wear particles and wear intensity.

Total contamination

For this purpose, apparatus CTT INFRA was applied. The apparatus is assigned for determination of contaminants total content in used motor, gear and hydraulic oils.

Mathematical method

With this method we get numeric values for determination of wear level and wear intensity. The test is carried out with magnetic analyser that directly reads numbers of small and large contaminant particles.

Experiment

The experiment itself was carried out on five diesel motors (of the same kind). Oil samples were withdrawn every 10 thousand kilometers, and then they were subject to the five chosen tribological methods. From each motor, four oil samples were tested.

Motor specification

- Diesel
- Cylinders 6
- Volume 11.94 litres
- Power 152 kW at 2000 rpm
- Torsional moment 840 Nm at 1200 – 1300 rpm
- Injection pressure 9 Mpa
- Cooling liquid volume 114.5 litres
- Cooling liquid working temperature 80 – 95 ºC

Measurement data
Vehicle #1

- Sample #1

Sampling mileage (km)	Measured values	Calculated values	Note
42,395	TC = 1.99% D_L = 29 D_S = 12 T_{flash} = 178 ºC H_2O…..none	WPC = 2.27% PLP = 0.7%	Oil was changed

Description: submicronic adhesive wear, good technical state, excellent friction regime, oil is capable of operation.

- Sample #2

Sampling mileage (km)	Measured values	Calculated values	Note
9,873	TC = 1.96% D_L = 35 D_S = 7 T_{flash} = 177 ºC H_2O…..none	WPC = 2.3% PLP = 0.83%	At sampling a defect on injection pump was eliminated

Description: good technical state, good friction regime, oil is capable of operation.

- Sample #3

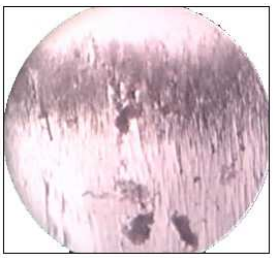
Sampling mileage (km)	Measured values	Calculated values	Note
20,026	TC = 1.93% D_L = 96 D_S = 10 T_{flash} = 197 ºC H_2O…..none	WPC = 5.88% PLP = 0.9%	

Description: small quantity of silicon particles, small quantity of adhesive particles, good technical state, good friction regime, oil is capable of further operation.

- Sample #4

Sampling mileage (km)	Measured values	Calculated values	Note
30,109	TC = 1.91% D_L = 60 D_S = 11 T_{flash} = 187 ºC H_2O…..none	WPC = 3.94% PLP = 0.85%	

Description: silicon and adhesive particles found in medium quantity, good technical state, good friction regime, oil is capable of further operation.



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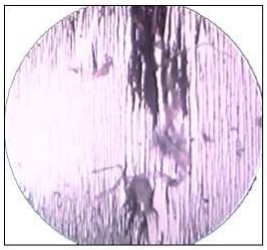

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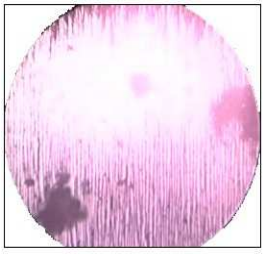

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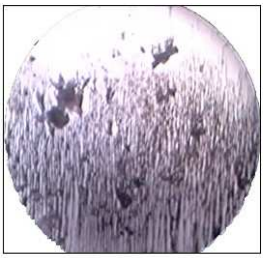

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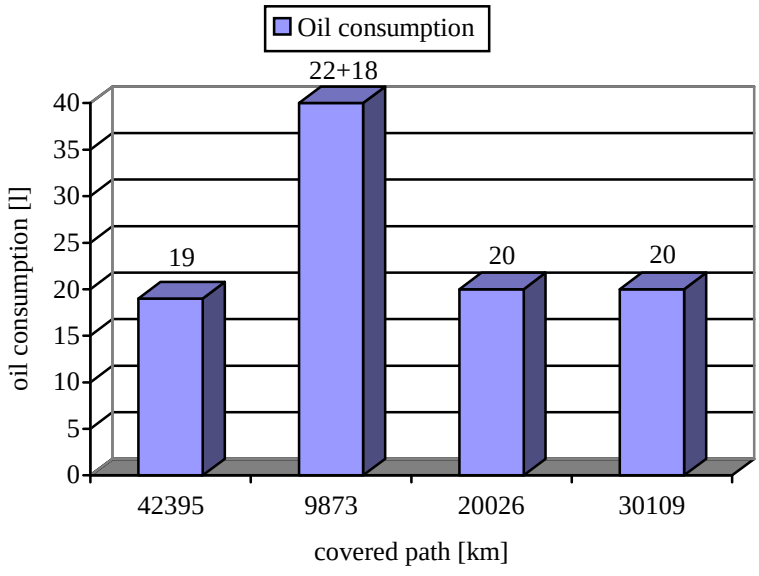


Vehicle #2

- Sample #1

Sampling mileage (km)	Measured values	Calculated values	Note
23,929	TC = 2.91% D_L = 740 D_S = 760 T_{flash} = 162 ºC H_2O…..none	WPC = 83.3% PLP = 34.53%	

Description: large quantity of adhesive particles, medium quantity of abrasive particles, friction regime is not satisfactory.
Recommendations: oil exchange, revision of fuel system.

- Sample #2

Sampling mileage (km)	Measured values	Calculated values	Note
34,015	TC = 2% D_L = 230 D_S = 20 T_{flash} = 186 ºC H_2O…..none	WPC = 13.88% PLP = 18.4%	Defect of oil tank screw cap

Description: medium quantity of abrasive and adhesive particles, good technical state, good friction regime, oil is capable of further operation.
Recommendation: revision of oil filtration.

- Sample #3

Sampling mileage (km)	Measured values	Calculated values	Note
9,893	TC = 2.2% D_L = 110 D_S = 14 T_{flash} = 170 ºC H_2O…..none	WPC = 6.8% PLP = 8.87%	Oil was changed

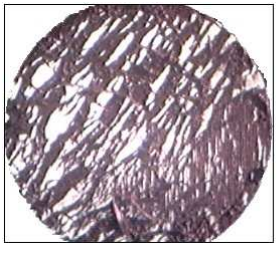
Description: large quantity of adhesive particles in, medium quantity of abrasive particles, silicon particles present, good technical state and friction regime, oil is capable of further operation.
Recommendation: revision of oil filtration.

- Sample #4

Sampling mileage (km)	Measured values	Calculated values	Note
20,018	TC = 2.3% D_L = 350 D_S = 180 T_{flash} = 130 ºC H_2O…traces 0.2%	WPC = 29.4% PLP = 19.8%	

Description: large quantity of adhesive particles, small quantity of abrasive particles.
Recommendations: oil exchange, revision of cooling system.

Sample #1



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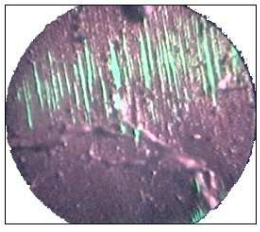

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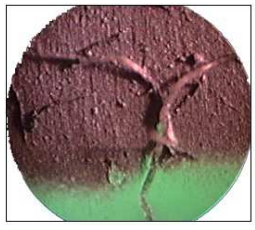

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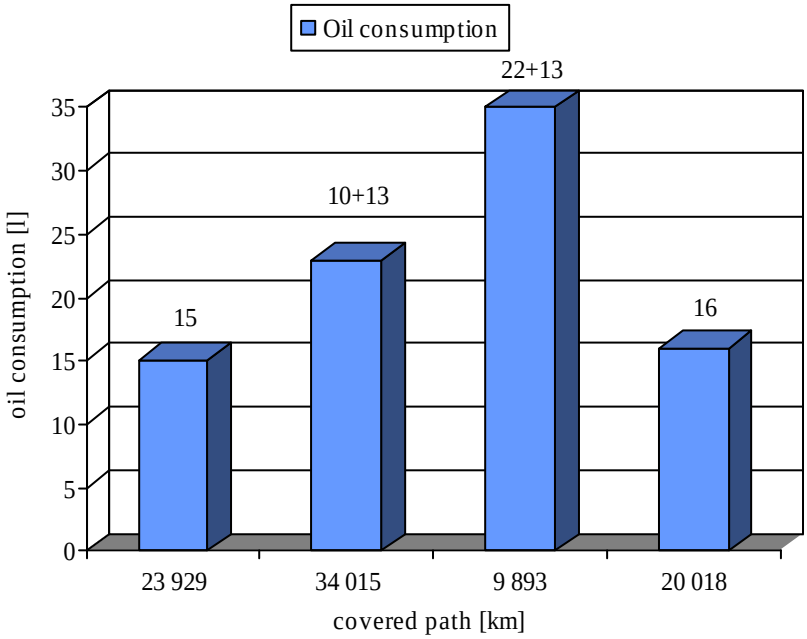


Vehicle #3

- Sample #1

Sampling mileage (km)	Measured values	Calculated values	Note
21,933	TC = 2% D_L = 14 D_S = 9 T_{flash} = 135 ºC H_2O…..none	WPC = 1.28% PLP = 0.61%	Oil was changed

Description: small quantity of adhesive particles, good technical state, excellent friction regime, oil is capable of further operation, fuel is leaking into oil.
Recommendation: revision of fuel system.

- Sample #2

Sampling mileage (km)	Measured values	Calculated values	Note
10,126	TC = 1.99% D_L = 43 D_S = 8 T_{flash} = 201 ºC H_2O…..none	WPC = 2.83% PLP = 0.84%	

Description: small quantity of abrasive and adhesive particles, fibres from filter present, good technical state, good friction regime, oil is capable of further operation.

- Sample #3

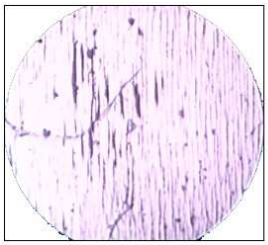
Sampling mileage (km)	Measured values	Calculated values	Note
20,194	TC = 2.1% D_L = 90 D_S = 10 T_{flash} = 166 ºC H_2O…..none	WPC = 5.5% PLP = 0.9%	

Description: small quantity of adhesive particles, silicon particles and fibres from air filter present, good technical state and friction regime, oil is capable of further operation.
Recommendation: cleaning of air filter.

- *Sample #4*

Sampling mileage (km)	Measured values	Calculated values	Note
29,952	TC = 2.1% D_L = 410 D_S = 290 T_{flash} = 135 ºC H_2O…..none	WPC = 38.9% PLP = 23.4%	

Description: large quantity of adhesive particles, small quantity of abrasive particles.
Recommendations: oil exchange; revision of fuel system, injections, circular and injection pumps; revision of centrifugal oil cleaner.



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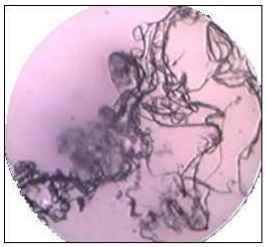

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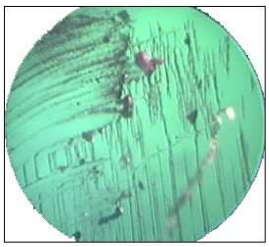

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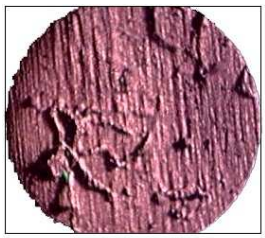

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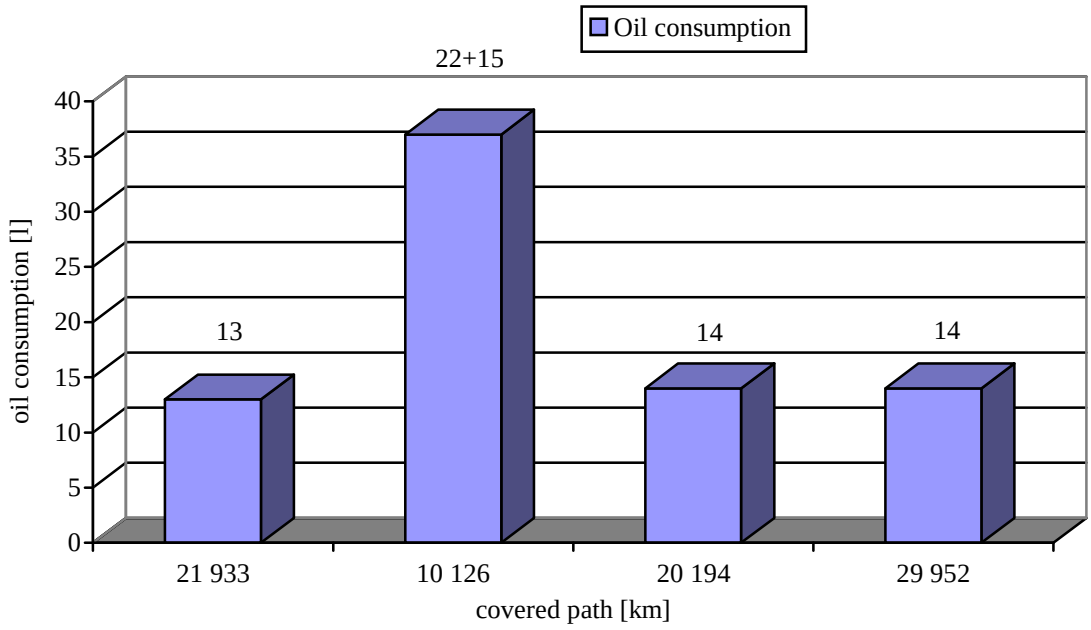


Vehicle #4

- Sample #1

Sampling mileage (km)	Measured values	Calculated values	Note
27,369	TC = 2.98% D_L = 30 D_S = 16 T_{flash} = 162 ºC H_2O…..none	WPC = 2.55% PLP = 0.65%	

Description: medium quantity of adhesive particles, satisfactory friction regime. Recommendations: revision of fuel system, oil exchange.

- Sample #2

Sampling mileage (km)	Measured values	Calculated values	Note
37,254	TC = 2.99% D_L = 192 D_S = 22 T_{flash} = 166 ºC H_2O…..none	WPC = 11.89% PLP = 8.97%	

Description: medium to large quantity of adhesive particles, medium quantity of abrasive particles, good technical state, good friction regime.
Recommendation: oil exchange.

- Sample #3

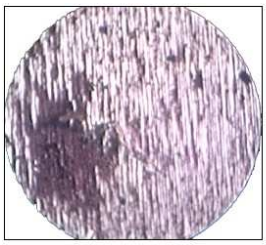
Sampling mileage (km)	Measured values	Calculated values	Note
10,213	TC = 2.1% D_L = 230 D_S = 15 T_{flash} = 177 ºC H_2O…..traces	WPC = 13.6% PLP = 18.7%	

Description: medium quantity of adhesive and abrasive particles, nonferrous metals present, water traces (from condensing) present, good technical state and friction regime, oil is capable of further operation.
Recommendation: revision of centrifugal oil cleaner.

- Sample #4

Sampling mileage (km)	Measured values	Calculated values	Note
19,931	TC = 2.96% D_L = 75 D_S = 15 T_{flash} = 130 ºC H_2O….traces approx. 0.2%	WPC = 38.9% PLP = 23.4%	

Description: small quantity of adhesive and abrasive particles, good technical state and friction regime, oil is capable of further operation.
Recommendations: oil exchange; revision of fuel and cooling systems.



Sample #1

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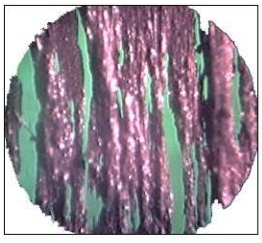

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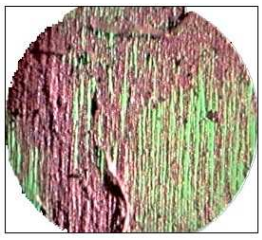

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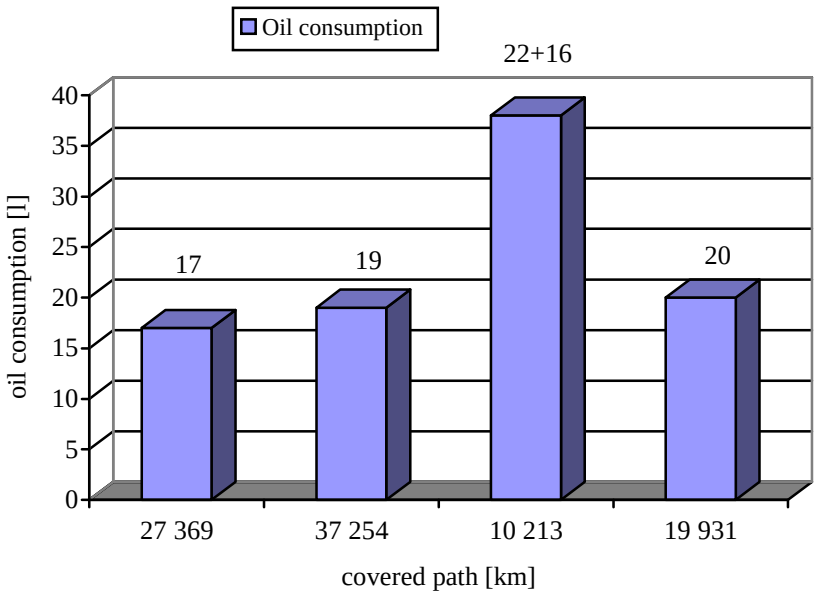


Vehicle #5

- Sample #1

Sampling mileage (km)	Measured values	Calculated values	Note
24,116	TC = 2.2% D_L = 62 D_S = 22 T_{flash} = 185 ºC H_2O…..none	WPC = 4.67% PLP = 0.74%	

Description: medium quantity of adhesive particles, small quantity of abrasive particles, good technical state, good friction regime, oil is capable of further operation.

- Sample #2

Sampling mileage (km)	Measured values	Calculated values	Note
33,986	TC = 1.89% D_L = 37 D_S = 7 T_{flash} = 173 ºC H_2O…..none	WPC = 2.44% PLP = 0.8%	

Description: small quantity of adhesive particles, small quantity of silicon particles, fibres from oil cleaner present, good technical state, good friction regime, oil is capable of further operation.

- Sample #3

Sampling mileage (km)	Measured values	Calculated values	Note
44,021	TC = 2.1% D_L = 387 D_S = 75 T_{flash} = 190 ºC H_2O…..none	WPC = 25.6% PLP = 25.1%	

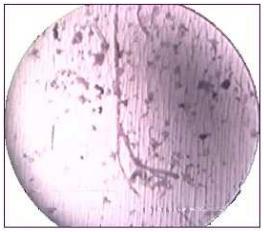
Description: medium quantity of large abrasive particles, large quantity of adhesive particles, nonferrous metals present, friction regime is not satisfactory or function of centrifugal cleaner is wrong, oil is capable of further operation.
Recommendation: revision of centrifugal oil cleaner.

- *Sample #4*

Sampling mileage (km)	Measured values	Calculated values	Note
54,102	TC = 2.85% D_L = 396 D_S = 204 T_{flash} = 124 ºC H_2O….traces approx. 0.2%	WPC = 33.3% PLP = 18.9%	

Description: large quantity of adhesive particles, small quantity of abrasive particles, medium quantity of silicon particles.
Recommendations: oil exchange; revision of cooling system.

Sample #1



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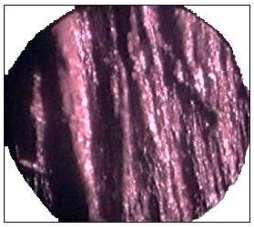

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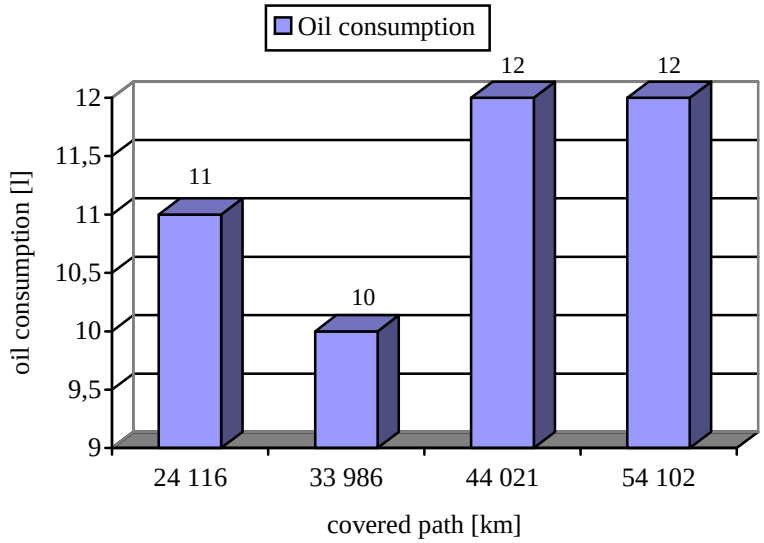

Legend

- *WPC* *wear particle concentration (the limit value 45 %),*
- *PLP* *percentage of large particles (the limit value 35 %),*
- *TN* *total contamination,*
- D_L *number of large particles,*
- D_S *number of small particles,*
- T_{flash} *flash point temperature.*

CONCLUSIONS

Apparently the main problem emerging from measurements is huge oil consumption of the observed vehicles. Such amounts of oil not only make the operation of the vehicles costly, but the situation does not fulfil requirements of EU standards. However, in Syria (and many other developing countries) standards usually are not as strict. Main reason for tribological diagnostic methods in these countries would be an effort to reduce operation costs of automobile park. The costs reduction consists of two parts: oil consumption (to be reduced), and damage prevention of vehicles. The damage prevention is done according to measurement data and sample observation that can show malfunction of vehicle subsystems such as oil cleaner defect, fuel system leakage or cooling system leakage.

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