D. NESTOROVIĆ, B. NEDELJKOVIĆ, D. STOJILJKOVIĆ

RESEARCH

Motor Oil Effects on Characteristics of Engine

Over the last decades there has been more and more severe requirements set to producers of motor vehicles and lubricants. Beside the fact they should provide functional, reliable and permanent operation, a vehicle as a whole is expected to give an adequate answer to wider and various market requirements in terms of environmental protection, improvement of vehicle performance, reduction of fuel consumption and increased traffic safety. When it comes to requirements related to lubricant characteristics, ways of use and intervals in which their replacement should take place, they are becoming more severe, since the motor vehicles' constructors keep making new and harder conditions in reference with performance improvement and lubricant effeciency.
This paper describes the results of motor oil quality measurements in relation with exterior speed characteristics of engine as well as the testing programme for oil in the engine on motor brake. The evaluation of motor oil quality is monitored by measuring sediments in vital parts of engine on one hand, and on the other, by measuring output characteristics of engine.

Keywords: *engine, oil, sediment, engine characteristics*

1. INTRODUCTION

During the vehicle exploitation, engine is exposed to weather changing, dynamic and unstationary loadings which are the function of a number of factors, such as: vehicle speed, loading, quality and weather conditions, etc. The changes in working regimes induce changes in operating loads, increases in operating temperature, wear and damage of engine parts. Dissipating processes created in that way result in undesirable effects that may be identified through loss of material, energy, characteristics, functionality and reliability, decrease in working life and grow of maintenance costs.

In order to reduce wear and damaging of engine parts, they must be lubricated. Selection of lubricants is conditioned by engine type and construction, by materials from which these elements are made of, by type and size of load, operating conditions and regimes of both engine and vehicle, lubrication method, etc. Lubricants may be considered to be a constructive element and therefore it is very important to know their composition, features and mechanism of effect. The complexity of lubrication system, the number of points to be lubricated (Figure 1) and various loads demand that motor oils should be chosen in such a way that they meet all the requirements in terms of wearing characteristics.

DR Dušan NESTOROVIĆ[1]
DR Branislav NEDELJKOVIĆ[2]
DR Dragana STOJILJKOVIĆ[3]
[1] "Zastava automobili", "Institut za automobile", Kragujevac, SCG
[2] "Zastava automobili", "PC Laboratorijum", Kragujevac, SCG
[3] "Masinski fakultet, Beograd,SCG

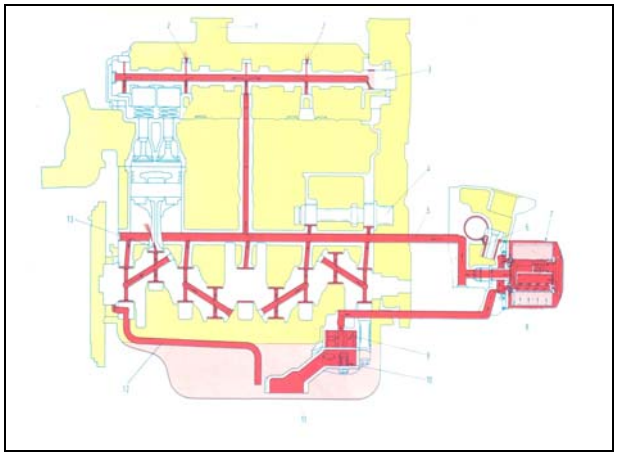


Figure 1: Lubrication scheme for Spark Ignition Engines

On the other hand, huge efferts have been made in order to reduce the harmful effects that automobiles have upon environment. Therefore, lubricating oil has already been applied world-wide with long periods between two replacements. In that way, through application of high-quality oil on one hand, the limited petroleum resources have been used econimically, while, on the other, the total quantity of used oil to be gathered and recycled is reduced in order to prevent its uncontrolled dissipation and environment pollution.

2. EXPERIMENTAL DETAILS

Going along with world trends that follow this problem, ″Zastava automobili″ and its suppliers of lubricants have started the activities related to introduction of oil with extended period of replacement for engine lubrication from its own programme. To that end, it's been constantly exploring motor oil both in engine test benches and in exploitation. The initial basis for bench testing of motor oil is the *CEC F-04-A-87* method *″Evaluation of sediments in petrol engines' intake system″*. For implementation of the CEC F-04-A-87 test, we use the engine of *OPEL Kadet 12S*, [1]. Zastava has modified this test for its own engine, where all influential, test-defined, values (intake air temperature, number of revolutions, load, test duration and assessment) have been adopted according to what is prescribed under basic test. Hereinafter, this test will be called the *modified CEC test*. For this test, as the representative one, we chose engine *128 A6.064*, being fitted into ″Zastava″vehicles. The test included the influence of oil to engine output characteristics through the measurement of sediments in the intake system as well as the exterior speed characteristics of engine. The exterior speed characteristics of engine were measured before and after the testing. The test alone lasts for 40 hours of engine running in the test bench in variable cycle conditions, that simulate city ride. Before the test start, engine is being run in for 5 hours and the engine is adjusted to prescribed values. As a fuel, we used the standard motor petrol IOB 95 which remained always the same, although the petrol quality was varied.

All the activities related to implementation of the modified CEC test can be divided in pre-testing, testing and post-testing activities.

The pre-testing activities include the following: calibration of measuring equipment, test engine running in (according to accurately defined conditions of basic test), inspection of all parts that are relevant for qualitative and quantitative assessment of sediments, mass measurement of intake and exhaust valves, fitting of new oil filter, checking the fuel supply system and all other adjustable engine characteristics.

Before the implementation of the first modified CEC test and all the checks planned under the research programme, engine had been run in in the test bench for 5 hours per cycle for the running in operation of engine that is included in the CEC test (Table 1).

Table 1: Engine running in cycle

TIME (MIN)	NUMBER OF REV. PER MIN.(REV/MIN) (± 50)
15	1000
15	1500
30	2000
30	2500
30	3000
90	3000
30	3500
30	4000
30	4500

After completing all the prep activities, you start the test that will last for 40 hours in total, according to the cycle of 4.5 minutes that is shown in Table 2 and that is repeated several times throughout the testing.

Table 2: Cycle of modified CEC test

Phase	Duration (min)	Number of revolutions per minute (rev./min)	Engine torque (Nm)	Temperature of imtake air (°C)	Output temperature of coolant (°C)	Oil temperature (°C)
1	0,5	1200±50	2,0 max	88±2	92 max	94 max
2	1,0	3000±50	35,3±2	88±2	92 max	94 max
3	1,0	1300±50	29,6±2	88±2	92 max	94 max
4	2	1850±50	32,5±2	88±2	90±2	92 ±2

Table 3: Operating conditions of the modified CEC test

	Measuring unit	Value
Number of revolutions	Rev./min	1850±50
Loading	Nm	32,5±2
Oil pressure	bar	min 1,5
Underpressure under throttle	mbar	to be measured
Cooling water intake temperature	°C	86±2
Cooling water output temperature	°C	90±2
Oil temperature in engine housing	°C	92±2
Intake air temperature	°C	88±2
Exhaust gas temperature	°C	to be measured
CO concentration	% Vol	to be measured

In the end of 4th cycle, there is a check and recording of the tersting conditions in every 4 hours. We read the values listed in Table 3.

All the listed values, except for oil pressure, exhaust gas temperature and CO concentration, are measured and monitored on the computer throughout all the phases of the modified CEC test. Oil pressure, exhaust gas temperature and CO concentration are measured separately and their values are written down in seperate tables.

For implementation of the modified CEC test we used the relevant *software* (Figure 2), so that all the measured data were saved and stored in the data base every second of this test implementation.

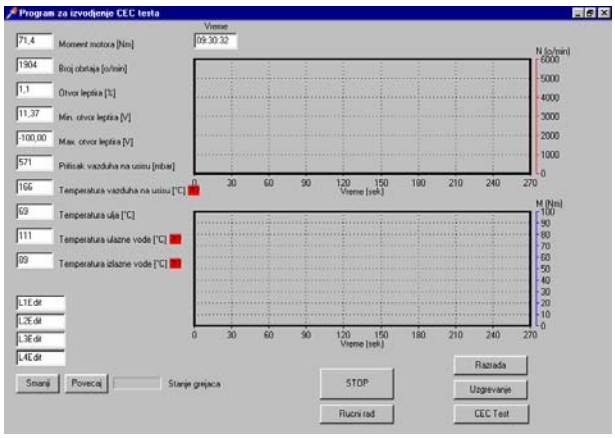


Figure 2: Application for working with motor brake W-130

After 40 hours of the modified CEC test implementation, the engine was stopped. After the engine stopped, oil is released and the quantity of oil released from engine is measured. In that way, we get the value of oil quantity consumed throughout the test implementation.

The assessment of sediments created throughout the test is conducted in three ways as follows:

- Method of visual assessment of intake valves, on the basis of sediment assessment scale of valves in *OPEL KADET,*
- Determining of sediment mass in intake valves and
- Visual inspection.

In the period of 50 hours at most after the testing completion, the cylinder head is to be removed and disassembled. After that, we conduct the assessment of intake valve head by visual check according to the scale of valve sediment assessment in *OPEL KADET*. The intake valves are set on a relevant support divided to 10%-segments and assessed through the valve head sediment together with lower part of valve stem (Figures 3 and 4). For each segment, there is a visual check of created sediment. The assessment is graded by numbers from 1 to 10. Grade 1 presents the least favourable case (the greatest quanity of sediment), whereas grade 10 is the most favourable case (practicaly clean valve), [1].

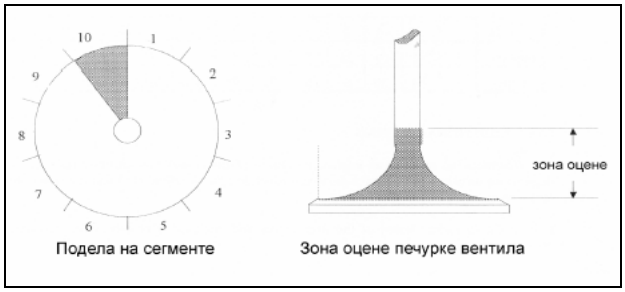
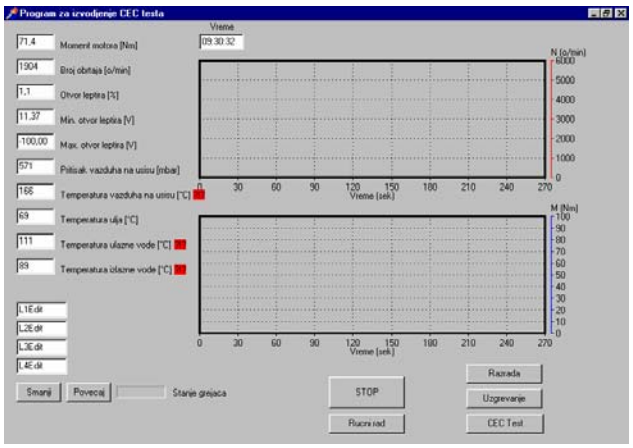


Figure 3: Division of valve head in segments and assessment zone



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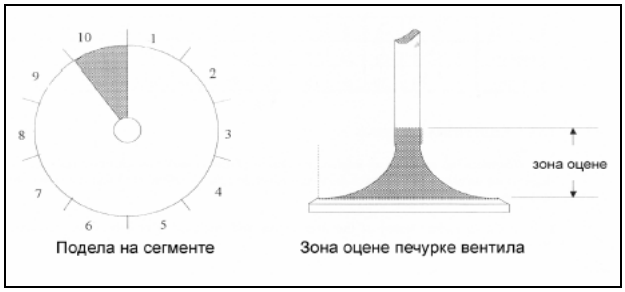

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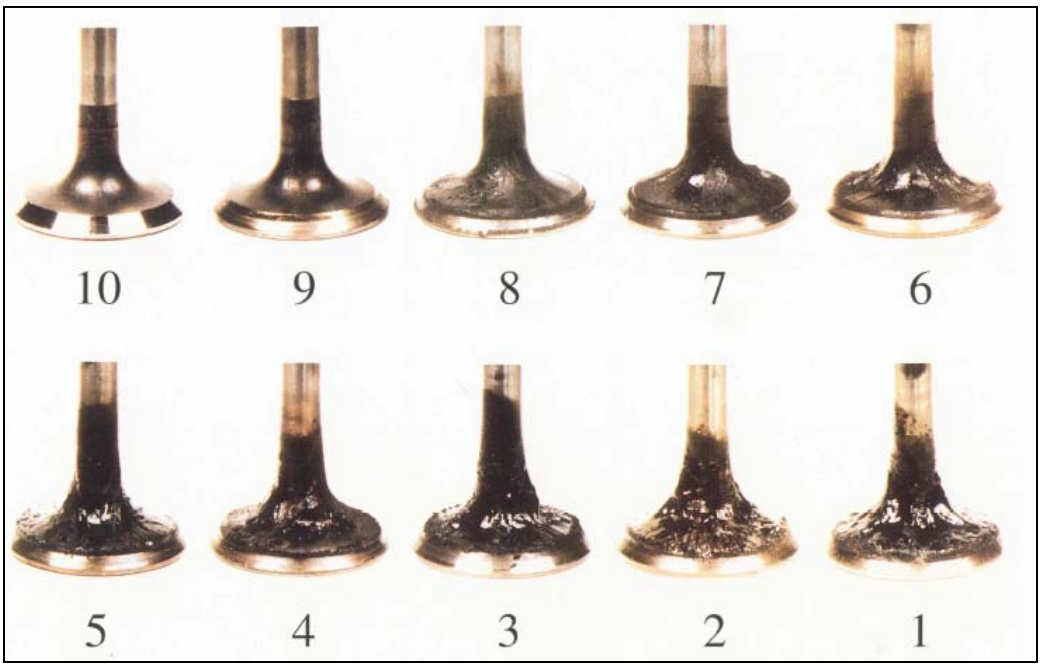

Figure 4: Assessment scale of sediment in OPEL Kadet valves

On the basis of visual check of the segment sediment the final assessment of created sediments is determined for the whole intake valve according to the following formula, [1]:

$$NV = \sum \frac{NSxOC}{100}$$

where:

NV – the sediment class of the whole intake valve,

NS – total sum of percentage of segments with the same sediment class,

OC – the class of created sediments for a certain sum of perecentages (NS)

The sediment mass is determined by measuring the mass of intake and outlet valves before and after the test. Before the repeated measuring of the valve mass in the test end, the sediments located in the combustion chamber and along the edges of intake and exhaust valves are to be carefully removed. The valves are then submerged in *n-heptan* for 10 seconds and air dried for at least 10 minutes. Each valve is then measured on a high-precision scale with accuracy of 1 mg.

In the end of each test, there is a visual inspection of sediments in the combustion chamber, spart plugs and piston face.

Influence of motor oil to output characteristics of engine are determined by recording the exterior speed characteristics of engine (power, torque etc. and fuel consumption) on motor brake, immediately after completing the CEC test, according to Standard 7.A6400. After that, we measure the oil consumption according to the prescribed procedure TU.7A6200

Oil quality testing according to the modified CEC test was performed in Laboratory for engines IA, on electrical motor brake *SCHENCK W-130*. Schematic display of measuring and developmental installation is given in the picture 5.

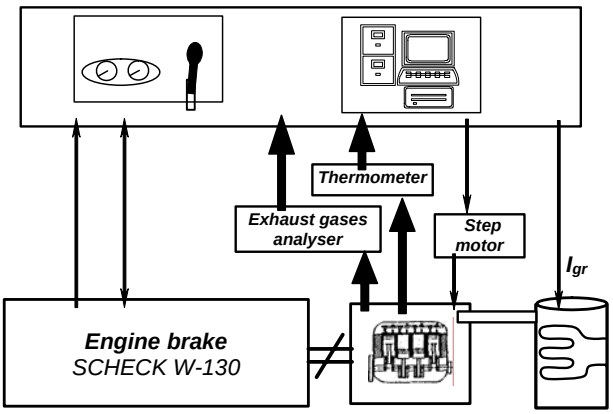

Figure 5: Schematic display of measuring and developmental installation

In order to enable correct and absolute repetitive modified CEC test performing, engine brake was adjusted and brought to a condition for operating in automatic regime. For this purpose, a computer was used, with a card for aquisition and controlling *ED2000* (12-bit resolution). Due to the proscribed conditions of modified CEC test performing, temperature of the intake air in the intake pipe was secured within the range of 88±2ºC during testing duration. Hot air was conducted into the engine intake filter from device for air heating whose volume is 200 dm^3 in which are 6 heaters with power 1,1 kW each. Heaters are activated automatically with PC computer on the basis of data on temperature in the intake pipe. Temperature sensor is installed in the air filter housing, which measures temperature of intake air. Step motor, which is through reductor (due to better resolution) connected with carburettor throttle plate axle, is controlled by computer and it gives desired position of the gas throttle. A certain *software* was written for controlling the engine brake and data acquisition. With each second of test performing all measured data are placed in the corresponding datafile.

Tests are carried out with four different samples of motor oil. Samples are marked with ordinal numbers from one to four. Their characteristics are given in the table 3, [2].

Table 4: Characteristics of motor oil samples for testing

Characteristic	Method	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Appearance	Visual	clear	clear	clear	clear
Density, 15^0C	ASTM D1298	0,88	0,88	0,88	0,88
KV/100	ASTM D445	14,7	15	14,98	15,3
KV/40		113,65	117,3	113,16	117,2
IV	ASTM	133	132	137	137

	D2270				
Ignition t°	ASTM D92	232	230	230	230
Foaming	ASTM D892				
- Seq. I -24^{0}C		10/0	0/0	10/0	0/0
- Seq. II -94^{0}C		20/0	15/0	30/0	10/0
- Seq. III -24^{0}C		0/0	0/0	10/0	0/0
Sulphate ashes, maximum	ASTM D874	0,9	0,8	1,0	1,3

3. TEST RESULTS

Appearance of the intake valves before and after testing is given in the figure 6.

Figure 6: Appearance of the intake valves before and after second modified CEC tests

Sediment results according to the modified CEC test are determined by visual assesment of sediment classes on the intake valves after each performed test,[2]. Based on the results of sediments classes determination for all tests and for all four intake valves, classes average value of arisen sediments was determined (table 5). Like it can be noticed, the *cleanest* intake valve (with highest sediment class) are with testing oil Sample No.2, and intake valve with the most sediment (with the smallest sediment class) are with oil application Sample No. 4.

According to the sediment mass determination method, quantity of the arisen sediments on each intake valve was determined (table 6).

From obtained results one can see uneven sediments quantity on engine cylinders valves, which is the result of uneven distribution of fuel mixture on cylinders.

Results obtained by recording the output engine characteristics, after performed sediment test, with different oil samples are shown in the picture 5, i.e. table 7.

Table 5: Average class values and intake valve sediment mass for all tests

Method	Oil sample No. 1	Oil sample No. 2	Oil sample No. 3	Oil sample No. 4
Arisen sediments class after scale OPEL KADET	**7,74**	7,94	7,63	**6,93**

Table 6: sediments masses on intake valves (g)

	Oil sample No. 1		Oil sample No. 2		Oil sample No. 3		Oil sample No. 4	
Valve No.	I test	II test	III test	IV test	V test	VI test	VII test	VIII test
1.	0,4122	0,3373	0,4267	0,3483	0,3034	0,3662	0,0151	0,2388
2.	0,6314	0,5259	0,0509	0,0450	0,3215	0,5852	0,5575	0,4525
3.	0,3275	0,2980	0,4580	0,1793	0,5711	0,0192	0,6616	0,6923
4.	0,4309	0,2779	0,5192	0,3145	0,3024	0,3421	0,2941	0,3735
Average	0,4505	0,3598	0,3637	0,2218	0,3746	0,3282	0,3821	0,4393
Average	**0,4051**		***0,2928***		**0,3514**		***0,4107***	

Table 7: Engine output characteristics

Oil sample	Power[kW] / Revolution. number [o/min]	Torque [Nm] / Revolution number [o/min]	Specific consumption [g/kWh] / Revolution number [o/min]
Sample No. 1	53,26 / 6000	93,99 / 3600	250,88 / 4000
Sample No. 2	***54,19 / 5600***	***96,85 / 3600***	***190,18 / 5000***
Sample No. 3	53,71 / 6200	95,64 / 3600	248,04 / 4000
Sample No. 4	***52,02 / 5600***	***93,09 / 3600***	***242,11 / 3000***

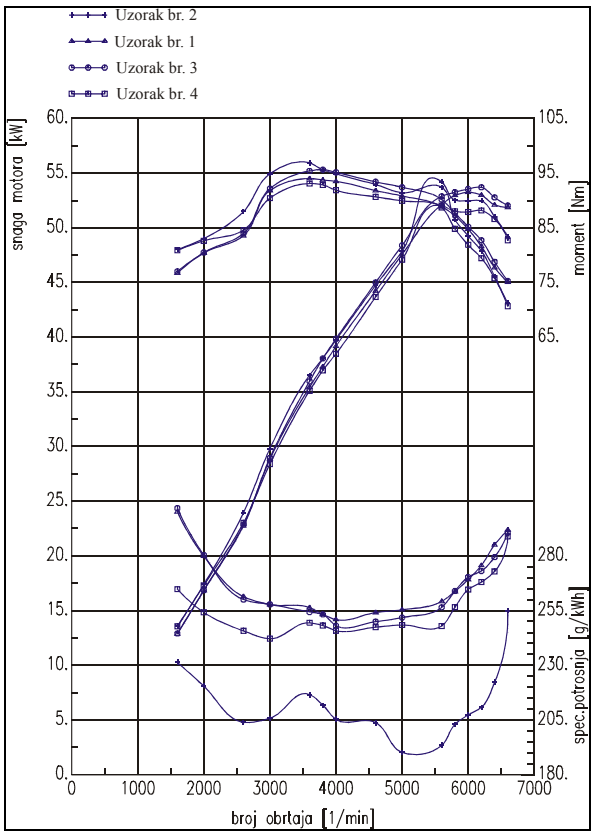

Figure 7: Engine output characteristics with different oil samples

From picture 7 one can notice that by using oil Sample No. 2 engine has the greatest power and torque and the least specific fuel consumption. Whereas by using oil Sample No. 4 the same results are the most unfavourable. By measuring the same values before sediment test with same oil samples, values are obtained in the measuring error.

4. CONCLUSIONS

Based on the performed engine tests on the test bench, with different motor oil samples, one can conclude that:

1. The cleanest intake valves (with highest sediment class) are with tests with oil Sample No. 2, and intake valve with the most sediment (with the smallest sediment class) are with oil application Sample No. 4.
2. Engine has the best characteristics when using oil Sample No. 2, and the worst with Sample No. 4.

REFERENCE

[1] Method *CEC F-04-A-87 "Sediment grade in the petrol engine intake system".*

[2] Report No. 48 IA about testing motor oils., Kragujevac, December 2004.

[3] Nestorovic D. , Spasojević S. : Testing additives effect on sediment creation in the engine, ZASTAVA, No. 37, Kragujevac, March 2004, p 41.

[4] Nestorovic D. , Reduction of Intake Valve Deposits Using Gasoline Additive, XIX NMV, Belgrade, 2003 J.