# THE METHOD OF CALCULATING THE LIMIT PARAMETER STATES CHARACTERISTIC OF OIL STATE

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***Abstract***

*In the majority of transport systems, they use the exploiting strategies where the use of oil is calculated in accordance to the following criteria:*
- *the distance in kilometers traveled,*
- *the time of engine work,*
- *petrol used by an engine.*

*When the value of one of the above criteria is reached, oil must be changed regardless its real state and its potential to be still used. If the oil potential was made use of, it would increase the effectiveness of the working system radically. The subject of the research are the changes of metal elements content in oil depending on lengthening the usage of examined oil.*

*The thesis shows the results the operation research of engine oil as well as the results of the research of models that calculate the limit states of the content of some metallic elements in tested oil. The exploiting research was based on the samples taken from engine oil of some bus makes. On the basis of the results of the exploitation research, according to the distance in kilometers traveled of buses, the content of metallic elements in examined engine oil has been calculated. On the basis of self research and literature analysis it has been stated that there is a lack of comfortable and reliable methods of assessing limit states of engine oil in transport systems. In the following thesis the attempt to lengthen the mileage of engine oil on the basis of calculating the change of the content of the crucial metallic elements has been taken.*

***Keywords:*** *model, limit state, concentration of use products*

## 1. Introduction

Oil is one of the most significant elements that appear in tribiological systems, among which there are internal combustion engines. There are the following friction knots:
- shaft neck – bearing liner
- cylinder sleeve - piston/rings.

As a result of the influence of the extracting factors, when an engine works, the purifying supplements in oil change their concentration and features.

The state of oil in the particular moment *t* can be described in the following formula (1):

$$\bar{x}(t) = \langle x_1(t), x_2(t), \ldots, x_n(t) \rangle, \tag{1}$$

where:

$x_i(t)$ - the value of a singular feature describing the state of oil in the *t* moment.

To specify the state of engine oil or another exploiting material it is necessary to fix the components, which values take into account the state of fresh oil and those, which describe staling changes.

The main reason for the difficulty in drowing up the universal methodology in forecasting the time of engine oil work is the lack of clear-cut guidelines in determining the links between the oil state and engine durability.

*Tab. 1. Comparison of limit values of some of the parameters of engine oil, according to different literature sources*

| No | Parameter | BN-79/0535-46 | Adamenko / Zelinskaia | A. Wachal | H. Krause | K. Baczewski | MAN | MTU | ElF Disola |
|---|---|---|---|---|---|---|---|---|---|
| 1. | **The viscosity kinematic in 100°C** | fall by 25%; max. 18,5 | 11.5-16.5 | -40%; +20% | -25%; +35% | -40%; +20% | 10.0÷17.0 | 10.5-19.0 | -15%; +25% |
| 2. | **Basic number TBN** | fall by 70% | min. 1.2 mg KOH/g | fall by 70% | fall by 70% | fall by 70% | min. 7 mg KOH/g | fall by 50% | min. 4 mg KOH/g |
| 3. | **Ignition temperature** | min. 175°C | min. 170°C | - | min. 150°C | min. 180°C | - | min. 190°C | min. 180°C |
| 4. | **Water content** | beneath 0.2% | beneath 0.05% | - | beneath 0.5% | - | - | beneath 0.2% | beneath 0.2% |
| 5. | **Iron concentration** | - | - | - | 100-150 ppm | - | max. 80 ppm | max. 70 ppm | - |
| 6. | **Chrome cincentration** | - | - | - | max. 20 ppm | - | max. 20 ppm | max. 15 ppm | - |

The hypothetical recommendations of products, which concern the use of oil in railway engines:

- MAN - 800 mth (around 25000 km);
- MTU - 1000 mth (around 30000 km);
- IVECO - 3500 mth (around 100000 km).

To sum up, in the majority of transport systems, they use the exploiting strategies where the use of oil is calculated in accordance to the following criteria:

- the distance in kilometers traveled,
- the time of engine work,
- petrol used by an engine.

When the value of one of the above criteria is reached, oil must be changed regardless its real state and its potential to be still used.

If the oil potential was made use of, it would increase the effectiveness of the working system radically.

*Tab. 2. The simulation of the profits taken from the usage of oil increase*

| No | Lengthin percentage [%] | The distance in kilometers traveled between oil exchange [km] | Annual Mount of oil exchange for one bus | Annual cost of oil for the whole stock (215) [zł] | Savings on oil cost per year [zł] |
|---|---|---|---|---|---|
| 1. | 10 | 22000 | 4.73 | 710616.28 | 70610.92 |
| 2. | 20 | 24000 | 4.33 | 650521.88 | 130705.32 |
| 3. | 30 | 26000 | 4.00 | 600944.00 | 180283.20 |
| 4. | 50 | 30000 | 3.46 | 519816.56 | 261410.64 |

## 2. The aim of thesis

The aim of the thesis is to draw a mathematical model describing the content of metal particles in engine oil that depends on the engine distance in kilometers traveled (described by the kilometers). To run the research it was necessary to take the samples of oil from the vehicles from December 2004 till April 2005 (together with the distance in kilometers traveled of the buses with 3828 and 3822 side numbers). There are either 16 or 17 measurement series of iron (Fe) and copper (Cu) particles.

## 3. The object and subject of the research

The object of the research is Tedex Diesel Truck SAE: 15W-40 engine oil used in the buses of the public transport in big cities.

The subject of the research are the changes of metal elements content in oil depending on lengthening the usage of examined oil.

## 4. Research methodology

The exploiting research was based on the samples taken every 2500 km up to 10000 km from engine oil of some bus makes. Later on, when the mileage was exceeded, the samples could have been taken every 1000 km. The aim was to calculate the content of crucial metal elements and the change of their value.

This thesis puts to the test lengthening the usage of engine oil on the basis of assessing the changes of the content of the significant metal elements.

## 5. The model of calculating the limit parameter states

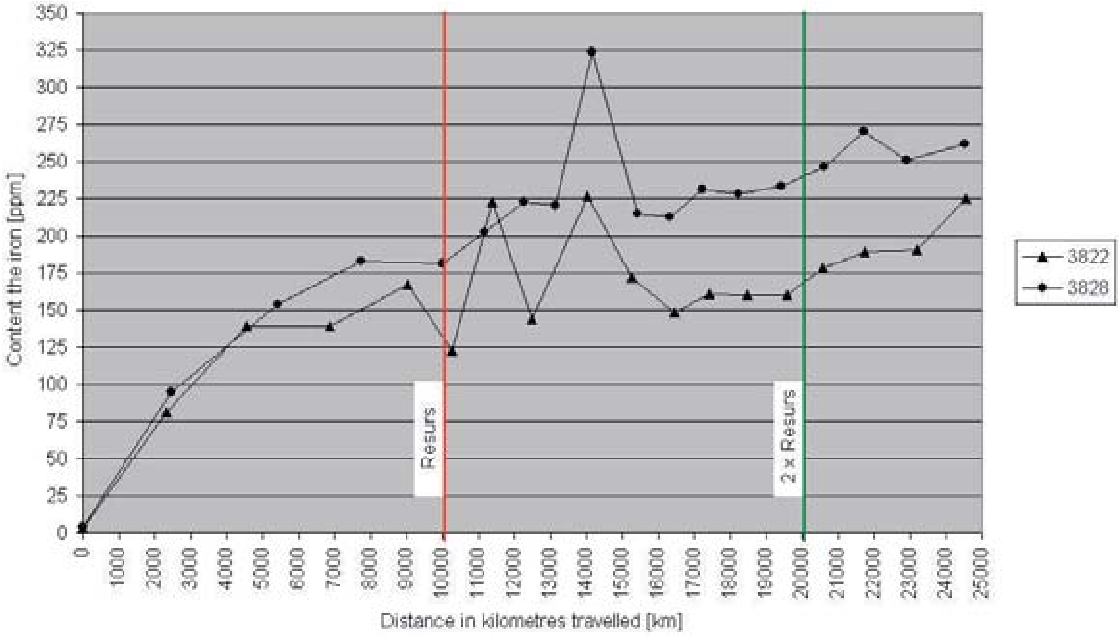


*Fig. 1. The change of iron content in oil samples according to the distance in kilometers traveled a bus*

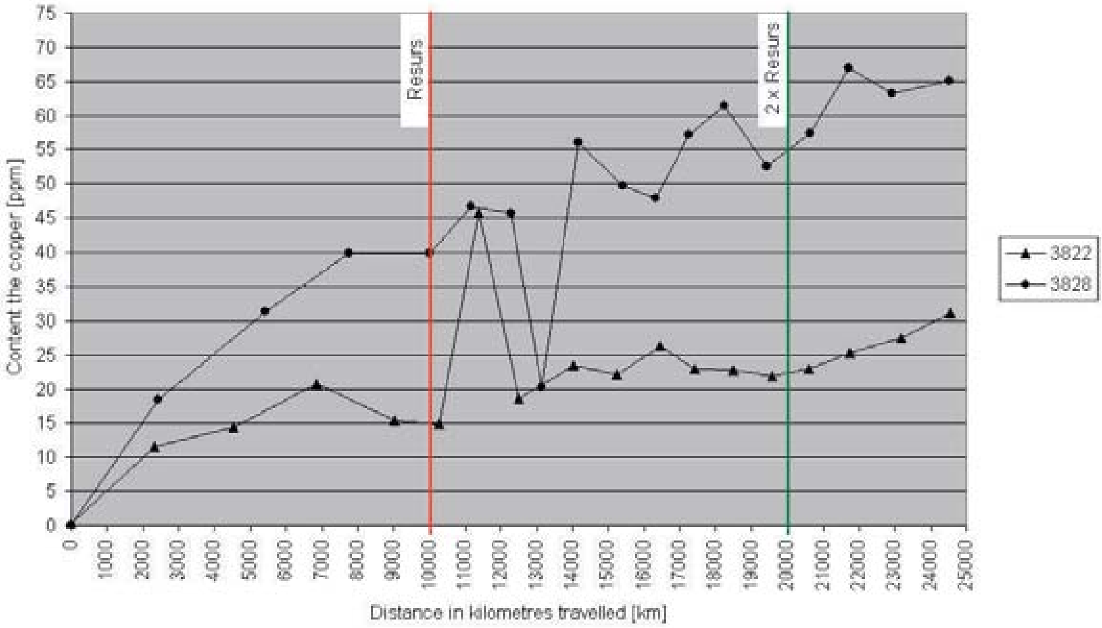


*Fig. 2. The change of copper content in oil samples according to the distance in kilometers traveled a bus*

The chart analysis of the link of the number of metal particles depending on a bus mileage let take a decision to draw mathematical models. There are two models sets:

$$Metal = \frac{a}{(\text{the distance in kilometres traveled})^2} + \frac{a}{\text{the distance in kilometres traveled}} + c \quad , \quad (2)$$

$$Metal = \frac{a}{\text{the distance in kilometres traveled}} + b \quad . \quad (3)$$

Metal means the number of metal particles (Fe or Cu).

For both models calculating the parameters was performed in Gretl programme. Some of the measures that stood behind in the series were deleted.

### 5.1. The models of type 1

The model of type 1

| | | | |
|---|---|---|---|
| Parameters: | a = 1.31883·109 | b = -1.00768·106 | c = 289.10 |
| p-value: | 0.00423 | 0.00004 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.9213$, | |
| Random change coefficient: | | 6.20% | |

Test for the decomposition of the rest of the model:
Zero hypothesis: determination coefficient has a normal decomposition
Test statistics: Chi-squared(2) = 0.6566 with p = 0.720 value
To conclude, there is no reason to reject the zero hypothesis.

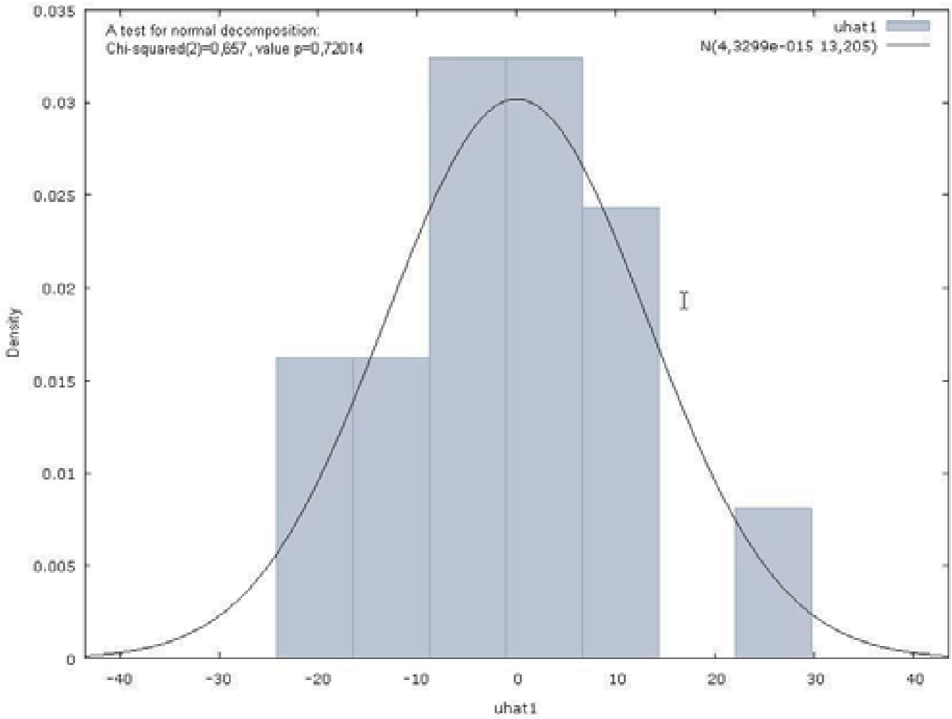


*Fig. 3. The chart of the rest of the model and a suitable normal decomposition*

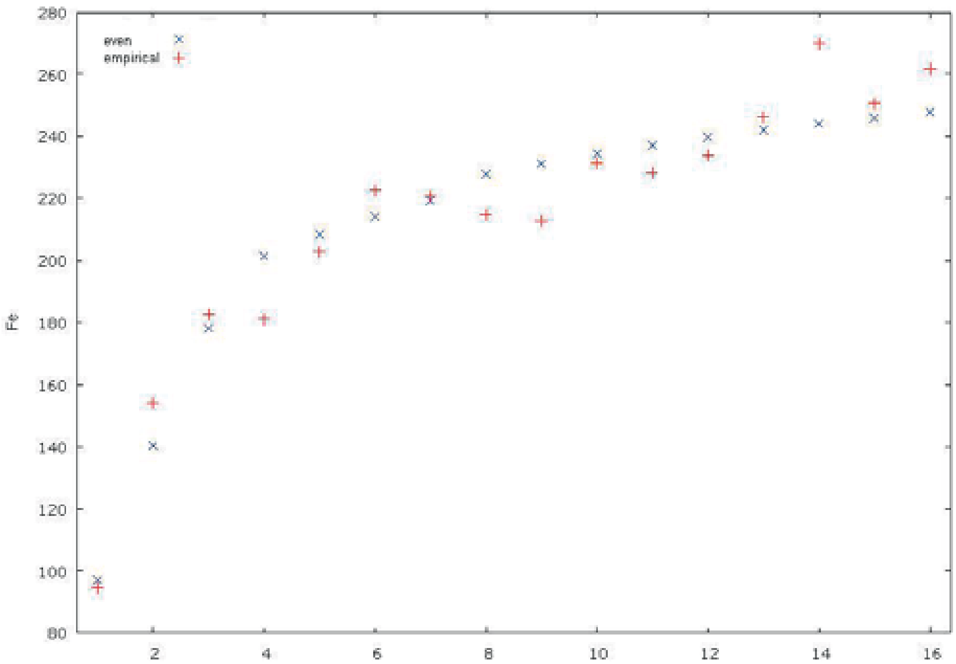


*Fig. 4. The empirical and even values of variable Fe*

The model for the 3822 bus (the content of Cu particles)

| | | | |
|---|---|---|---|
| Parameters: | a = 2.29784·108 | b = -139520 | c = 31.01 |
| p-values: | 0.03 | 0.00476 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.671$, | |
| Random change coefficient: | | 15.18% | |

Test for the decomposition of the rest of the model:

| | | |
|---|---|---|
| Zero hypothesis: | determination coefficient has a normal decomposition | |
| Test statistics: | Chi-squared (2) = 0.188223 | with p = 0.910 value |

To conclude, there is no reason to reject the zero hypothesis.

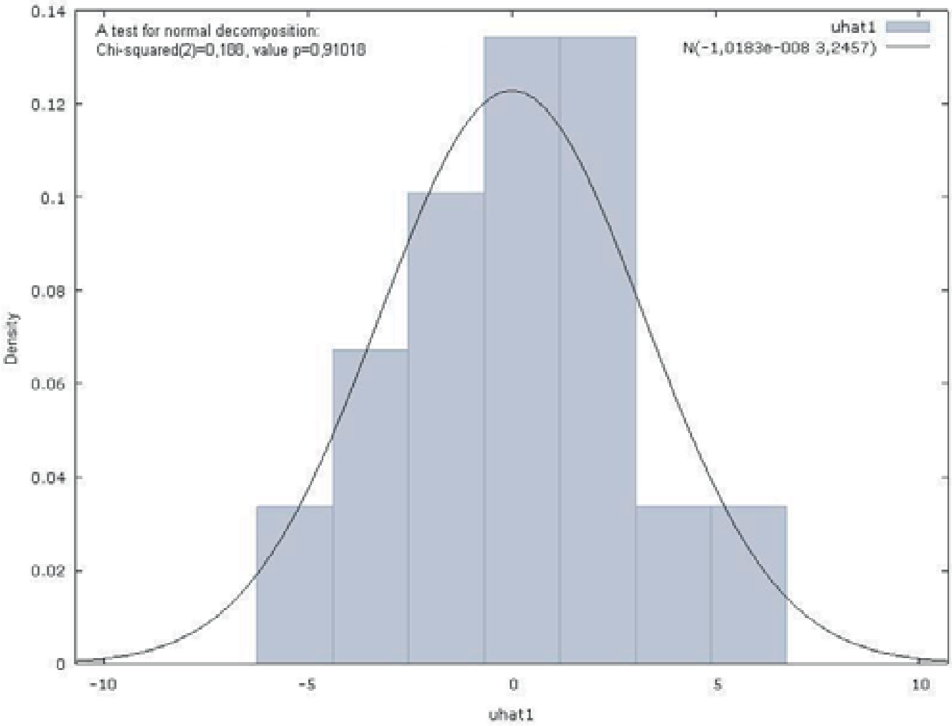


*Fig. 5. The chart of the rest of the model and a suitable normal decomposition*

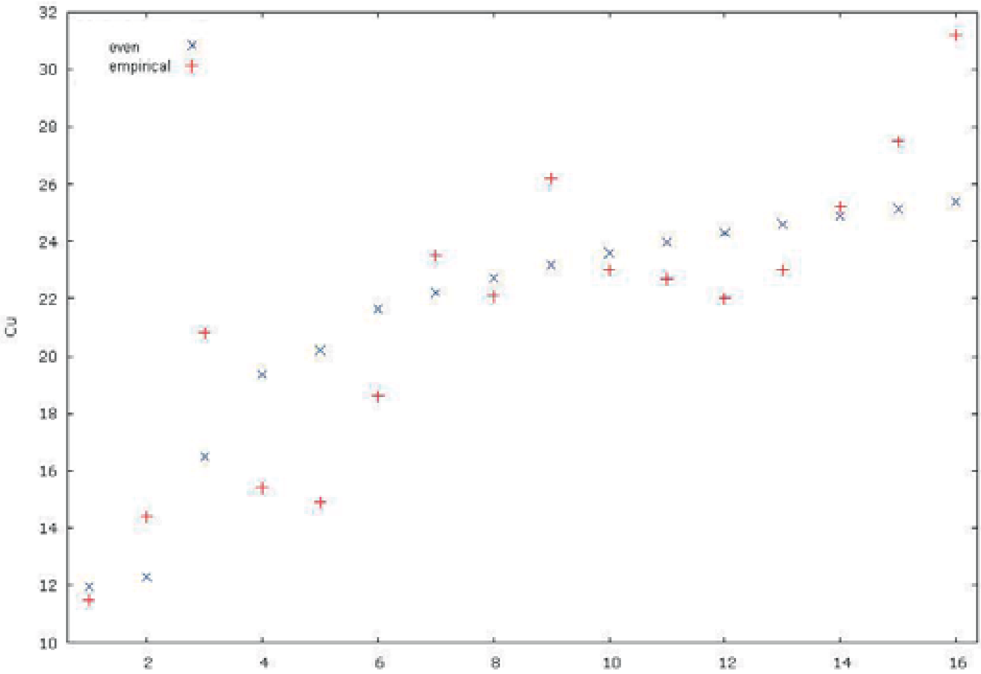


*Fig. 6. The empirical and even values of variable Cu*

### 5.2. The models of type 2

| | | |
|---|---|---|
| Parametry: | a = -42110 | b = 25.4684 |
| p-value: | 0.00160 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.521$ |
| Random change coefficient: | | 17.66% |

Test for the decomposition of the rest of the model:
Zero hypothesis: determination coefficient has a normal decomposition
Test statistics: Chi-squared (2) = 0.136229 with p = 0.506 value
To conclude, there is no reason to reject the zero hypothesis.

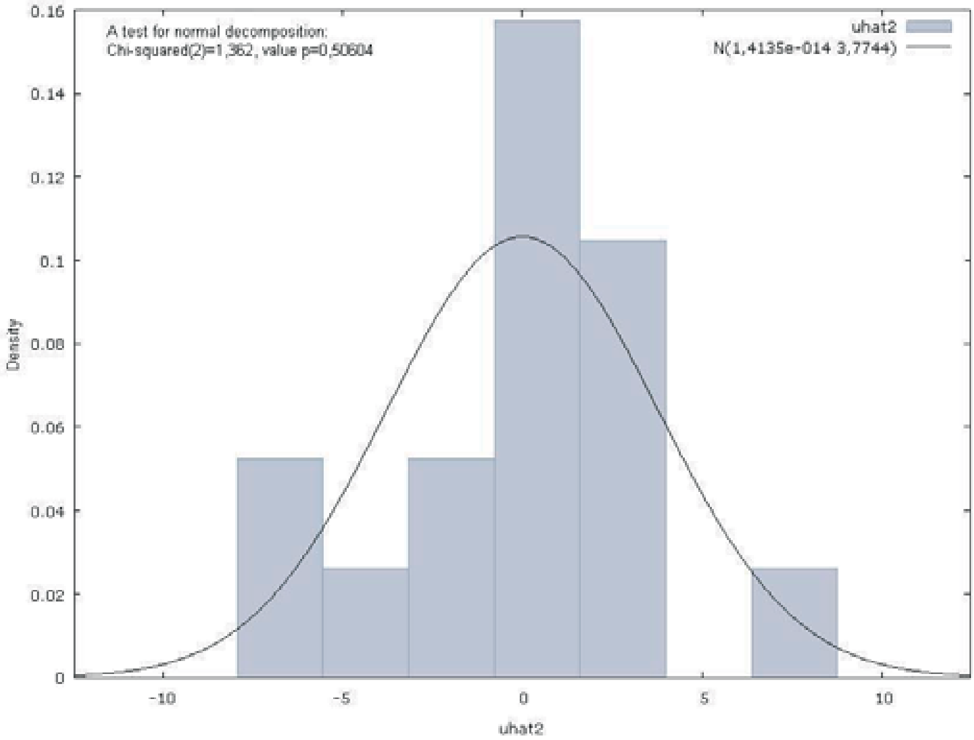


*Fig. 7. The chart of the rest of the model and a suitable normal decomposition*

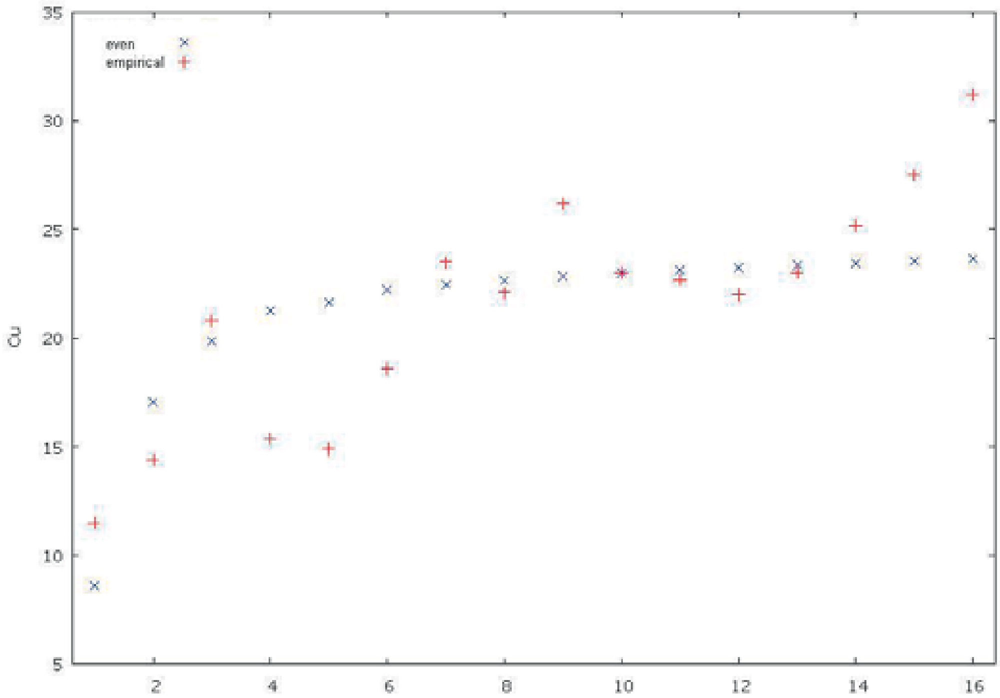


*Fig. 8. The empirical and even values of variable Cu*

The model for the 3822 bus (the content of Fe particles)
The model of type (2) seems to be the best one.

| | | |
|---|---|---|
| Parametres: | a = -283333 | b = 190.209 |
| p-value: | 0.00197 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.507$ |
| Random change coefficient: | | 16% |

Test for the decomposition of the rest of the model:
Zero hypothesis: determination coefficient has a normal decomposition
Test statistics: Chi-squared (2) = 2.6049 with p = 0.272 value
To conclude, there is no reason to reject the zero hypothesis.

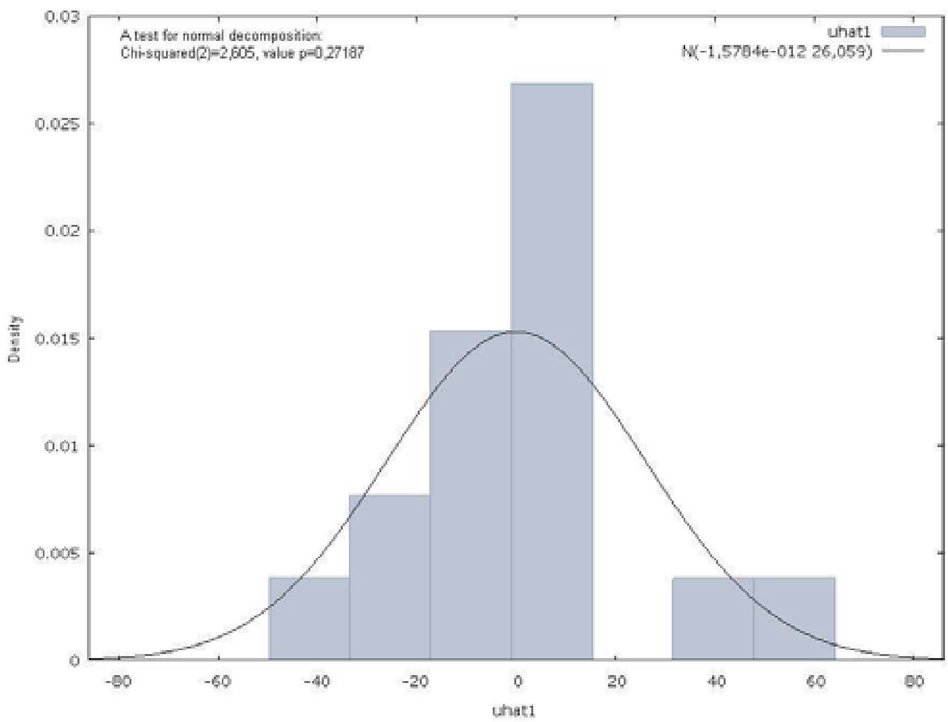


*Fig. 9. The chart of the rest of the model and a suitable normal decomposition*

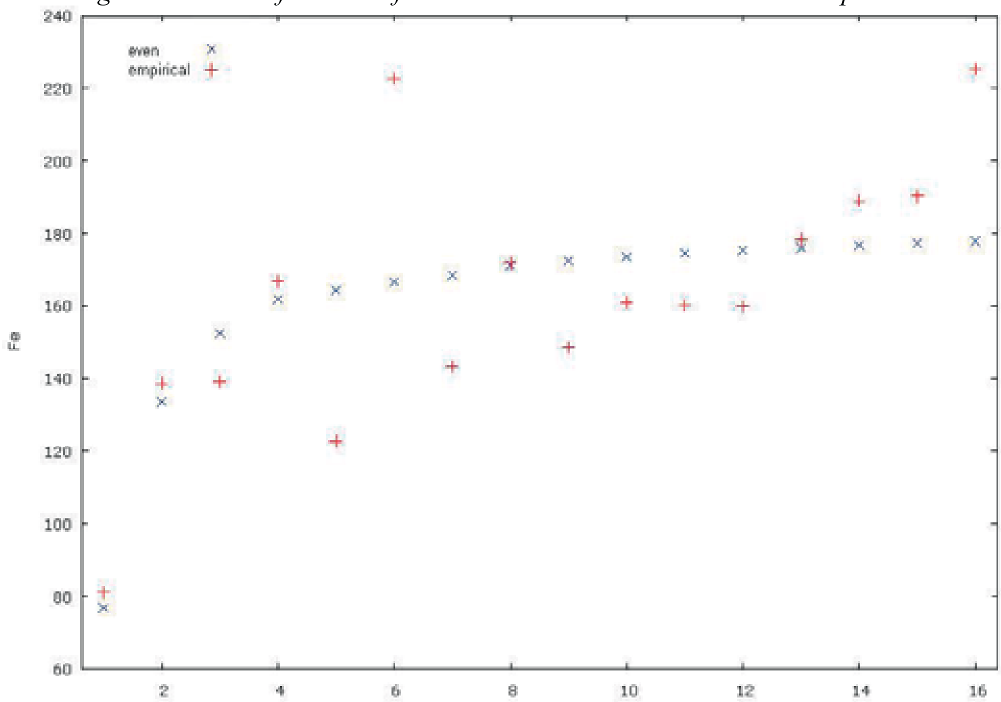


*Fig. 10. The empirical and even values of variable Fe*

The model for the 3828 bus (the content of Fe particles)

| | | |
|---|---|---|
| Parametres: | a = -448234 | b = 256.993 |
| p-values: | 0.00001 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.8489$ |
| Random change coefficient: | | 8.28% |

Test for the decomposition of the rest of the model:

Zero hypothesis: determination coefficient has a normal decomposition

Test statistics: Chi-squared (2) = 0.48384 with p = 0.78512 value

To conclude, there is no reason to reject the zero hypothesis.

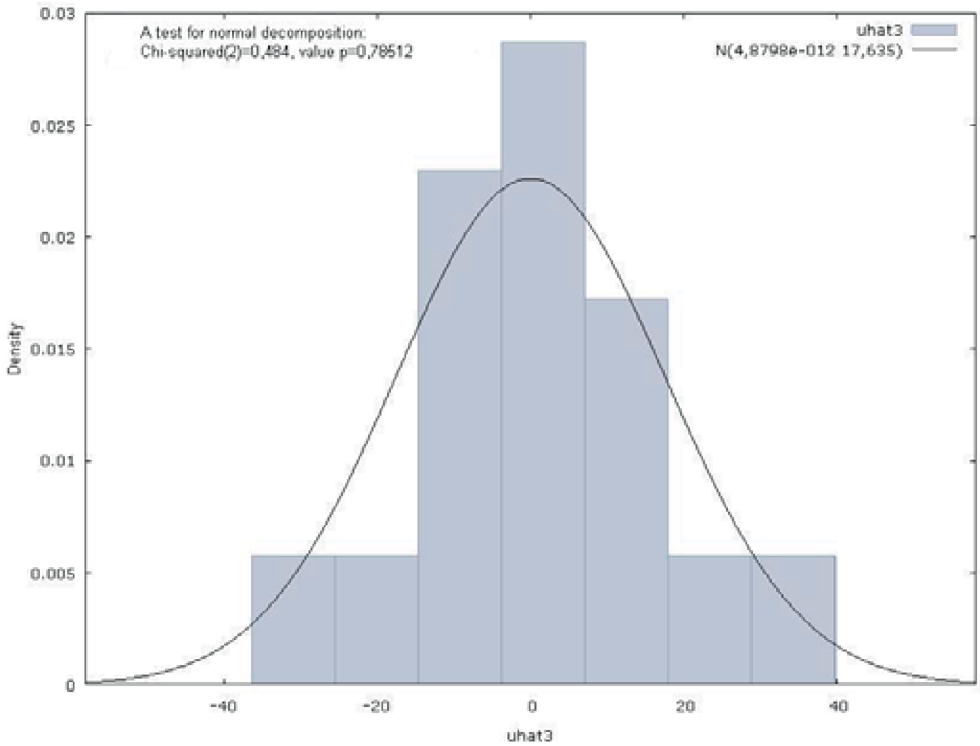


*Fig. 11. The chart of the rest of the model and a suitable normal decomposition*

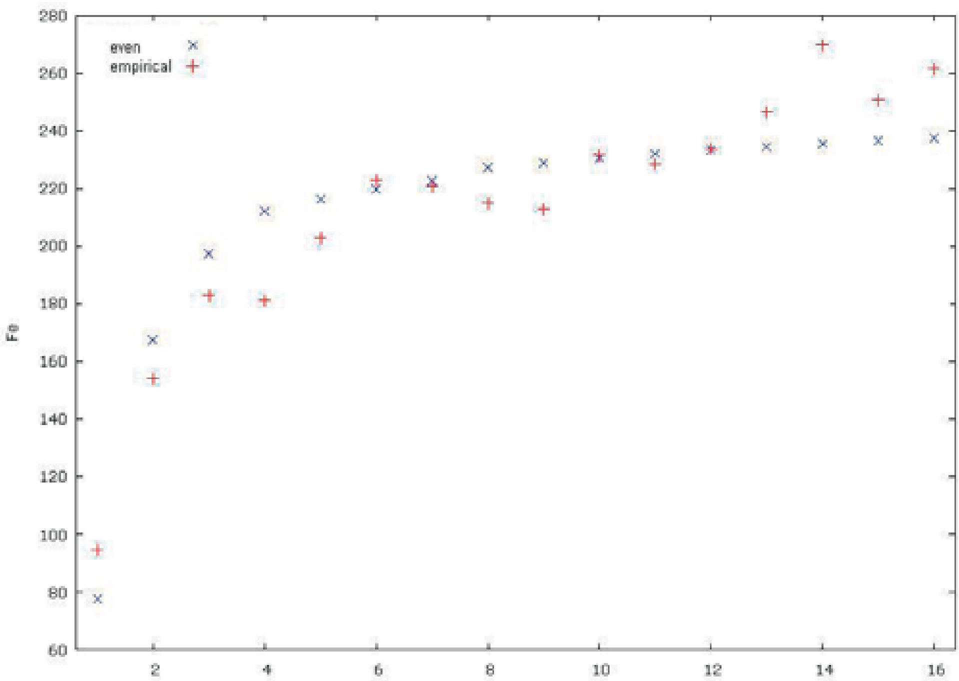


*Fig. 12. The empirical and even values of variable Fe*

The model for the 3828 bus (the content of Cu particles)

Both models (1) and (2) were estimated for the content of Cu. The determination coefficient seems to be more suitable for the (1) model, but the hypothesis of the rest decomposition should be rejected. There are only the results of model (2) calculations.

| | | |
|---|---|---|
| Parameters: | a = -120328 | b = 59.5328 |
| p-values: | 0.00138 | 0.00001 |
| Determination coefficient: | | $R^2 = 0.530$ |
| Random change coefficient: | | 22.14% |

Test for the decomposition of the rest of the model:

Zero hypothesis: determination coefficient has a normal decomposition

Test statistics: Chi-squared (2) = 7.7472 with p = 0.021 value

To conclude, there is no reason to reject the zero hypothesis on the 0.01 level

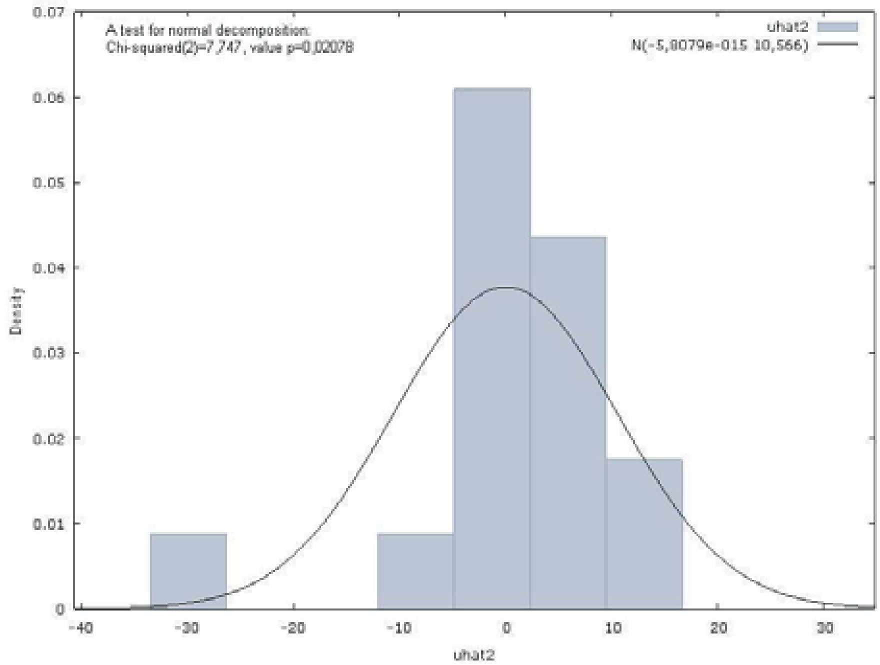


*Fig. 13. The chart of the rest of the model and a suitable normal decomposition*

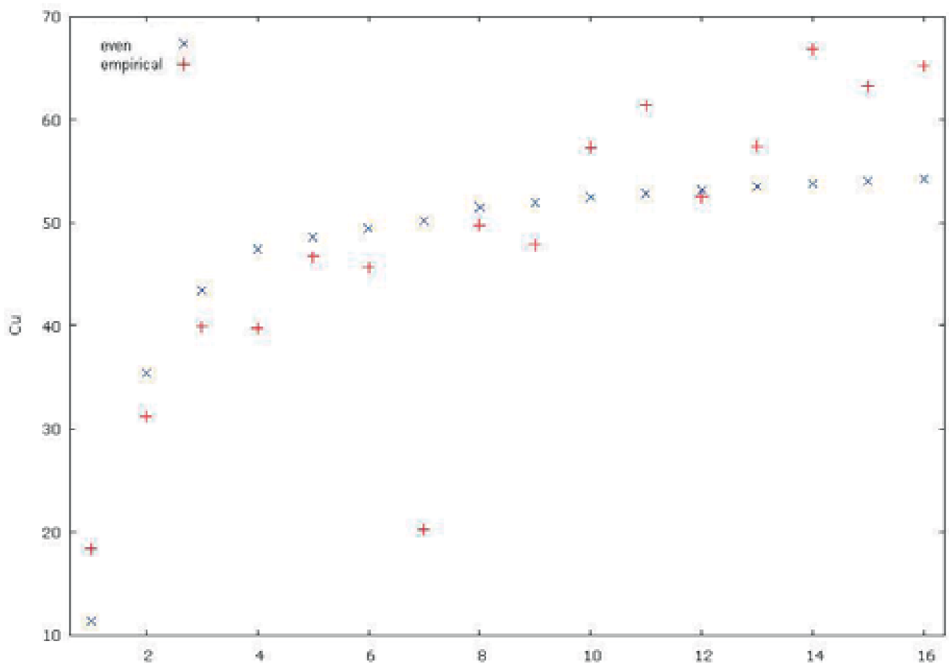


*Fig. 14. The empirical and even values of variable Cu*

## 6. The analysis of the results and conclusion

The results of the research of a product concentration of using tribiological knots has been presented in a graphical form.

The models of type 1 (2) and type 2 (3) for the 3822 and 3828 buses let estimate the limit values of metal particles (Fe and Cu) in engine oil used after the long distance in kilometers traveled term. Tab. 3 includes the values given as a result of calculating.

*Tab. 3. The list of limit values of the basic oil contents*

| Bus code | Metal symbol | Limit values of metal particles |
|---|---|---|
| 3822 | Fe | Model of double-parameter: 190.209 |
| 3822 | Cu | Model of double-parameter: 25.47 |
| | | Model of tria-parameter: 31.01 |
| 3828 | Fe | Model of double-parameter: 256.99 |
| | | Model of tria-parameter: 289.10 |
| 3828 | Cu | Model of double-parameter: 59.53 |

The Gretl programme (http;//www.gretl.sourceforge.net) is the GNU GENERAL PUBLIC LICENCE programme.

There is a necessity to build a model of estimating the value of the limit states parameters that describe the oil values such as the full basic number, the kinematic viscosity, the ignition temperature. The description of the values and the level of concentration of the significant metal elements in engine oil helps to build a model of estimating the state limits of the crucial engine oil parameters.

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