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SURFACE PLASMON RESONANCE - A PROMISING METHOD FOR ESTIMATING THE QUALITY OF MOTOR OIL
OPTIMIZATION OF MAGNETIC FLUX IN ELECTROMAGNETIC VIBRATING GENERATORS

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Abstract: Recent development in manufacturing of rare-earth permanent magnets provides a large variety of their shapes and magnetic properties. Ring shaped permanent magnets, mainly FeNdB magnets with high magnetic flux density (1.5 T), are frequently used for the construction of electromagnetic vibrating power generators for example in battery electric vehicles. The key parameter for optimal construction is the efficiency of power conversion which characterizes how effectively vibrating power generator converts kinetic energy into electric energy and stores it in batteries. The presented contribution brings an overview of concepts which increase this efficiency: 1) magnetic structure of axial magnets with like-poles facing each other incorporating soft magnet spacers; 2) cylindrical Halbach array magnetic structure; 3) outer magnetic shield structure for the concentration of magnetic flux. In the experimental section is also introduced constructed prototype of electromagnetic vibrating power generator and measurements of induced voltages.

Keywords: RARE-EARTH PERMANENT MAGNET, ELECTROMAGNETIC VIBRATING GENERATOR, MAGNETIC FLUX, MAGNETIC STRUCTURE, MAGNETIC SHIELD.

1. Introduction

Recent development in construction of battery electric vehicles brings a possibility to extend their driving range by a recovery of the excess kinetic energy. Besides recovery of the kinetic energy during the regenerative breaking of battery electric vehicles, also concepts dealing with the conversion of vibrating kinetic energy of wheels back into electric energy have been published [1-3]. Ring shaped permanent magnets, mainly FeNdB magnets with high magnetic flux density (up to 1.5 T), are frequently used for the construction of electromagnetic vibrating power generators for electric vehicle [1, 2]. The design of electromagnetic linear vibrating generator can be explained in model of magnetic circuits [4, 5] consisting from 1) axial magnets with like-poles facing each other, 2) soft ferromagnetic spacers, 3) air gaps, where undesirable leakage of magnetic flux occurs, 4) magnetic shield, which eliminates magnetic flux leakages into the open space. Various cylindrical Halbach array magnetic structures have been studied to minimize magnetic flux leakages [2]. Suggested double-concentric Halbach array seems to be effective in concentration of magnetic flux. However the construction of such magnetic structures is very difficult and expensive.

Although air gaps are disadvantageous for the vibrating generator, on the other hand they are essential for multiple copper coil windings placed on the moveable non-magnetic holder. Dimensions of holder with copper induction coils must be optimally designed to eliminate the magnetic flux leakage into the coil windings (see Fig. 1).

2. Theoretical part

Figures 1, 2 show right part of parallel magnetic circuits axially magnetized by permanent magnets (white portions with red arrows). Blue portions of the circuits (spacers) are made from soft ferromagnetic material. Spacers redirect the magnetic flux $\Phi$ in the radial direction and represent shunts of magnetic circuits. Each spacer generates the leakage of the magnetic flux into the open space (red arrows in Fig. 1, 2). Thus the magnetic circuits have to be closed by soft magnetic shield. During the vibration motion (upward and downward) of copper winding with velocity $v$, the axial component of the magnetic flux density $B_z$ alternates in the winding cross-section area $S$. From Faraday’s induction law the EMF voltage $U_i$ induced in the winding of $N$ turns is:

$$U_i = \frac{\partial \Phi}{\partial t} = 2NB_zSv.$$  

Fig. 1 Scheme of magnetic circuits displaying non-optimal magnetic flux circulation through air gaps.

Fig. 2 Scheme of magnetic circuits with optimized magnetic flux circulation by inserted moveable soft magnetic portions (yellow).
Further important construction parameter is the maximum current $I_{\text{max}}$ generated by the vibrating coils with short circuit:

$$I_{\text{max}} = \frac{U_i}{R} = \frac{B_z S \nu \pi d^2}{2 \rho_{Cu} L_w},$$

where $\rho_{Cu}$ is the electrical resistivity of copper, $L_w$ is the copper winding length of vibrating coils and $d$ is copper wire diameter.

### 3. Experimental part

For the analysis of magnetic flux we have adopted the four-phase linear generator (Fig. 3) containing ring-shaped permanent FeNdB magnets, which are arranged with like-poles of adjacent magnets facing each other to redirect the magnetic flux in the radial direction. The concentric outer cylinders made of soft magnetic high permeable (spacers) are used to overcome the repulsive forces between magnets and concentrate magnetic flux. The improved coil assembly consists of holder with copper coils separated with moveable soft magnetic rings, as it is schematically displayed in Figure 2. The use of high magnetically permeable material optimally conducts the magnetic flux far from spacers and increases radial flux density circulation. Figure 4 shows EMF voltage $U_i$ induced in the four windings of experimental prototype of electromagnetic vibrating generator during the vibration motion (upward and downward). The peak voltage of each winding corresponds to Equation 1. After connection of the selected winding to a rectifier set-up with short circuit the measured maximum current has been slightly lower than theoretically predicted in Equation 2. The explanation is the eddy current loss which occurs inside moveable soft magnetic rings at low frequencies ($< 10$ Hz).

4. Results and discussion

The experiments have been performed with and without magnetic shield to estimate magnetic flux leakages into the open space. The experimental prototype of electromagnetic vibrating generator without magnetic shield, as displayed in Fig. 3, was only able to produce approximately half of theoretically predicted EMF voltage $U_i$ in Equation 1. Using the magnetic shield increases magnetic flux density in cross-section of copper winding by more than 50%.

![Fig. 3 Experimental prototype of electromagnetic vibrating generator. From the left hand side is the „backbone” consisting from FeNdB permanent magnets and soft ferromagnetic spacers. The improved coil assembly consisting of holder with copper coils during the vibration motion (upward and downward).](image)

![Fig. 4 EMF voltage $U_i$ induced in the windings of experimental prototype of electromagnetic vibrating generator (from Fig. 3) during the vibration motion (upward and downward) with magnetic shield.](image)

5. Conclusion

In the presented paper the construction of electromagnetic linear vibrating generator is optimized and tested by means of: 1) the magnetic shield, which eliminates magnetic flux leakages into the open space, increases magnetic flux density in cross-section of copper winding; 2) the improved coil assembly consisting of holder with copper coils separated with moveable soft magnetic rings; 3) the use of high magnetically permeable materials optimally conducting the magnetic flux far from spacers and increasing the radial flux density circulation; 4) induction coils optimally designed to eliminate the magnetic flux leakage into the coil windings.

Nevertheless the further research is necessary to increase the maximum current when the winding is connected to the rectifier set-up with short circuit.

Acknowledgement

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References

DIRECTIONS FOR LOAD AND SAFETY APPRECIATION OF CARRYING STRUCTURES COMPONENT ELEMENTS

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Abstract: This paper presents the directions for load and safety appreciation of carrying structures component elements and their application to a particular object respectively carrying structure of rotating excavator working wheel. Load and safety of the carrying structure and its component elements are estimated based on the calculation of load and safety factors. The estimated load is based on the calculated value of load factors, while the safety by comparison of the calculated safety factors to the values of recommended minimum safety factors obtained by examinations of such structures in practice. With these indicators we have a situation where we are providing the static strength control of the analyzed elements. The paper presents numerical values of the load and safety coefficients for the excavator SRs-630 working in the coalmine "Suvodol" Bitola, for all characteristic working regimes in its exploitation lifetime. The numerical values of load and safety coefficients relate to clamps of the working wheel carrying structure and the most loaded joint of this structure.

Keywords: LOAD COEFFICIENT; SAFETY COEFFICIENT; CARRYING STRUCTURE; CLAMPS; ROTATING EXCAVATOR.

1. Introduction

Load and safety appreciation of the component elements for a steel carrying structure is necessary to analyze the derived results of the examination of its stress-deformed shape. For this purpose, we are evaluating the stress shape of the separate element on the structure and the stress shape for the whole carrying structure.

From the computer attained images for local stress shape on the structure’s element, which is subject of interest, we are performing a reading of stress values and perceived its layout in the metal structure of the element. For uniform stresses, the assessment of the stress shape of the element is made on the basis of the reported structure of the element. For uniform stresses, the assessment of stress shape is performed on the basis of the equivalent stress that takes into account the normal and tangential stresses and which is calculated by the famous phrase:

$$\sigma_e = \sqrt{\sigma^2 + 3\tau^2}$$  \hspace{1cm} (1)

To evaluate the load of the element we are using the load coefficient \(k_{oi}\), which is calculated by the following equation:

$$k_{oi} = \frac{\sigma_{e_{\text{max}i}}}{\sigma_{oi}}$$  \hspace{1cm} (2)

where:

- \(\sigma_{e_{\text{max}i}}\) - maximum equivalent stress for the element \(i\) of the carrying structure for a particular load regime
- \(\sigma_{oi}\) - medium stress for the element \(i\)

$$\bar{\sigma}_{oi} = \frac{1}{2}(\sigma_{e_{\text{max}i}} + \sigma_{e_{\text{min}i}})$$  \hspace{1cm} (3)

The load of the lattice carrying structure with \(n\) structural elements, overall for a load regime (working regime) is evaluated based on the average load coefficient \(k_{o}\) of the construction, which is calculated regarding the following equation:

$$\bar{k}_o = \frac{1}{n} \sum_{i=1}^{n} k_{oi}$$  \hspace{1cm} (4)

Analog indicators may be performed, and the load of separate elements could be done with a different load regimes. In this case we are calculating the medium load coefficient \(k_{o_{\text{max}}}\) of the element \(i\) for \(m\) load conditions, according to the following equation:

$$k_{oi}^{\text{max}} = \frac{1}{m} \sum_{j=1}^{m} k_{oj}$$  \hspace{1cm} (5)

where:

- \(k_{oj}\) - load coefficient of the element \(i\) in the \(j\)-th load regime

The control of the static strength for the structural element \(i\) of the carrying structure is implemented by comparing safety coefficient \(n_{oi}\) to minimum safety coefficient \(n_{\text{min}}\) by the equation:

$$n_{oi} = \frac{\sigma_{doci}}{\sigma_{e_{\text{max}i}}} \geq n_{\text{min}}$$  \hspace{1cm} (6)

where:

- \(\sigma_{doci}\) - permissible stress for the material of the structural element

The medium safety coefficient \(n_{oi_{\text{max}}}\) of the element \(i\) for \(m\) load conditions, is calculated by the following equation:

$$n_{oi}^{\text{max}} = \frac{1}{m} \sum_{j=1}^{m} n_{oj}$$  \hspace{1cm} (7)

2. Aspects in load and safety appreciation for specific real object

The above theoretical listed directions for load and safety appreciation of the component elements of carrying structures in this paper are applied to a carrying structure of rotating excavator, particularly to the working wheel carrying structure of the rotating excavator SRs-630 (Figure 1) and working conditions in the coalmine "Suvodol" which is placed in Bitola, R. Macedonia. This carrying structure is with lattice constructive design in console type, which supports two clamps bearing in the upper structure of the excavator. The geometric model of this carrying structure is shown in Figure 2.

Determining the general stresses of carrying structure of the rotating excavator and its clamps, the same one it’s possible with their appropriate modeling and using the methods for matrix analysis of structures, which gives indicators of global stress shape. The local stresses as a characteristic of separate areas of the structure cannot be identified in this review of the carrying structure.
in this model of an overview. For determination of the local stresses, it is necessary to isolate parts of the structure that are the main overview of interest as stress shape and to consider them as separate spatial structural elements. In this case with application finite element method (FEA method) which is most appropriate for this purpose and suitable computer program are modeled the structural elements with spatial finite element in idealized form with a sufficient extent of closeness to the real element.

For the excavator SRs-630 characteristic working regimes for mentioned coalmine are:

*Regime I* - Horizontal position (of the working wheel carrying structure) and turning left;
*Regime II* - Horizontal position (of the working wheel carrying structure) and turning right;
*Regime III* - Uppermost position (of the working wheel carrying structure) and turning left;
*Regime IV* - Uppermost position (of the working wheel carrying structure) and turning right;
*Regime V* - Nethermost position (of the working wheel carrying structure) and turning right;
*Regime VI* - Nethermost position (of the working wheel carrying structure) and turning right.

3. Load and safety appreciation

**Load coefficients for the clamps and carrying structure**

The load coefficient \( k_{oi} \) and medium stress \( \bar{\sigma}_{ei} \) for both clamps on the carrying structure of rotating excavator SRs-630 for specified characteristic on working regimes of the excavator, which was examined their stress-deformed shape, are calculated by the aforementioned equations and given in Table 1.

<table>
<thead>
<tr>
<th>Load regime</th>
<th>Medium stress ( \bar{\sigma}_{ei} ) [kN/cm²]</th>
<th>Load coefficient ( k_{oi} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>right clamp</td>
<td>left clamp</td>
</tr>
<tr>
<td>I</td>
<td>5.55</td>
<td>5.04</td>
</tr>
<tr>
<td>II</td>
<td>5.55</td>
<td>5.04</td>
</tr>
<tr>
<td>III</td>
<td>5.54</td>
<td>5.05</td>
</tr>
<tr>
<td>IV</td>
<td>5.55</td>
<td>5.05</td>
</tr>
<tr>
<td>V</td>
<td>5.54</td>
<td>5.05</td>
</tr>
<tr>
<td>VI</td>
<td>5.55</td>
<td>5.05</td>
</tr>
</tbody>
</table>

The load coefficient \( k_{oi} \) and medium stress \( \bar{\sigma}_{ei} \) for most loaded joint of the carrying structure of rotating excavator SRs-630, or joint 24, for all six working regimes of the excavator that was examined its stress-deformed shape are given in Table 2.

<table>
<thead>
<tr>
<th>Load regime</th>
<th>Medium stress ( \bar{\sigma}_{oi} ) [kN/cm²]</th>
<th>Load coefficient ( k_{oi} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>most loaded joint</td>
<td>most loaded joint</td>
</tr>
<tr>
<td>I</td>
<td>5.00</td>
<td>2.00</td>
</tr>
<tr>
<td>II</td>
<td>5.00</td>
<td>2.00</td>
</tr>
<tr>
<td>III</td>
<td>6.00</td>
<td>2.00</td>
</tr>
<tr>
<td>IV</td>
<td>6.00</td>
<td>2.00</td>
</tr>
<tr>
<td>V</td>
<td>5.50</td>
<td>2.00</td>
</tr>
<tr>
<td>VI</td>
<td>5.50</td>
<td>2.00</td>
</tr>
</tbody>
</table>

For load and safety appreciation of the component element of carrying structure and the structure as a whole, it is necessary to conduct an analysis of its global and local stress-deformed shape repeatedly, or for different loads of the structure that would take into account all different working regimes of the excavator. We are making a conclusion for load and safety of the carrying structure as a whole, on the evaluation of these parameters for its most loaded joint that is with riveted design (shown in Figure 1), and located in conducted a global analysis of state-deformed shape for this construction.

![Fig. 1: View of the rotating excavator SRs-630, the working wheel carrying structure being marked with red pointer.](image1)

![Fig. 2: Geometric model of the clamps and carrying structure with the layout of all the joints with the most loaded joint marked by red pointer.](image2)
The medium load coefficient $k_{oi}^{max}$ for the clamps and working wheel carrying structure of the excavator for all regimes are provided in Table 3.

<table>
<thead>
<tr>
<th>Load regime</th>
<th>Medium load coefficient $k_{oi}^{max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>right clamp</td>
<td>left clamp</td>
</tr>
<tr>
<td>I - VI</td>
<td>1.99</td>
</tr>
</tbody>
</table>

Safety coefficients for the clamps and carrying structure

The safety coefficient $n_{oi}$ for clamps and working wheel carrying structure of the excavator SRs-630 for the characteristic regimes of the excavator that was studied their stress-deformed shape is calculated by the aforementioned equations and presented in Table 4.

<table>
<thead>
<tr>
<th>Load regime</th>
<th>Safety coefficient $n_{oi}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>right clamp</td>
<td>left clamp</td>
</tr>
<tr>
<td>I</td>
<td>2.52</td>
</tr>
<tr>
<td>II</td>
<td>2.52</td>
</tr>
<tr>
<td>III</td>
<td>2.52</td>
</tr>
<tr>
<td>IV</td>
<td>2.52</td>
</tr>
<tr>
<td>V</td>
<td>2.52</td>
</tr>
<tr>
<td>VI</td>
<td>2.52</td>
</tr>
</tbody>
</table>

Empirical data for the excavators indicates that working wheels are carrying structure on the minimum bases with a coefficient with a value $n_{min}=1.3$.

The yield strength of material for the clamps and II case of loading is $\sigma_f=36\, \text{kN/cm}^2$, and the permissible tension stress has a value $\sigma_t=36\, \text{kN/cm}^2$.

The yield strength of material for the joint 24 and II case of loading is $\sigma_{f}=24\, \text{kN/cm}^2$, and the permissible tension stress has a value $\sigma_{to}=18.4\, \text{kN/cm}^2$.

Medium safety coefficient $n_{oi}^{max}$ for the clamps and working wheel carrying structure of the excavator for the six working regimes is given in Table 5.

<table>
<thead>
<tr>
<th>Load regime</th>
<th>Medium safety coefficient $n_{oi}^{max}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>right clamp</td>
<td>left clamp</td>
</tr>
<tr>
<td>I - VI</td>
<td>2.52</td>
</tr>
</tbody>
</table>

4. Conclusion

The paper provides directions for the load and safety appreciation for the component element of the carrying structures and displays their application at specific real object. The paper presents load and safety data for the working wheel carrying structure and its clamps for the excavator SRs-630, and also presents the working conditions of the same one into the coalmine "Suvodol" Bitola, R. Macedonia. These parameters presented into the paper enable verification of the static strength of the carrying structure and its clamps.

For the specific excavator the load coefficient $k_{oi}$ for the right clamp is 1.99 and for left clamp is 1.98 and for all working regimes, and therefore the medium load safety coefficient $k_{oi}^{max}$ for the clamps has the same value. For most loaded joint of the carrying structure value of this coefficient is 2.00.

The safety coefficient $n_{oi}$ for the left clamps is bigger than the safety coefficient for the right clamp, for all listed working regimes. For the right clamp the medium safety coefficient $n_{oi}^{max}$ has a value of 2.52 while for left clamp is 2.77. The safety coefficient $n_{oi}$ for most loaded joint for all regimes is lower than the safety coefficients for the clamps. For this joint the medium safety coefficient has a value of 1.68.

The values of the load coefficients for the clamps and most loaded joint of the carrying structure are within the values for these ratios derived from examinations of similar rotating excavators working in the approximate working conditions.

The values of the safety coefficients for the clamps and most loaded joint of the carrying structure and towards it and for all of its joints are bigger than the minimum safety coefficient $n_{min}=1.3$ for carrying structures, derived from previous researches on rotating excavator in the world frames.

The derived results for the safety coefficient magnitudes in this paper can be generalized to clamps and carrying structures of other rotating excavator with a similar geometry and comparable working conditions.

5. References

FUZZY PROPORTIONAL DERIVATIVE APPROACH FOR VIBRATION CONTROL OF VEHICLES

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Abstract: In this paper a fuzzy logic proportional derivative controller is proposed for suppressing vertical vibrations of vehicles. Initially quarter vehicle model is presented. Afterwards fuzzy proportional derivative approach is described in order to minimize vertical displacement of vehicle body. The proposed controller is applied to quarter vehicle model to demonstrate and evaluate performance of the controller. Time responses of vehicle body displacement, acceleration and suspension deflection are compared between controlled and uncontrolled cases. The proposed controller exhibits promising behavior.

Keywords: FUZZY LOGIC, PROPORTIONAL, DERIVATIVE, VIBRATION CONTROL, QUARTER VEHICLE

1. Introduction

Traditionally vehicle vibrations are controlled by passive suspension systems. A passive suspension system is composed of spring and damper elements. The control objectives cannot be achieved in broadband frequencies with these systems. Therefore, there occurs tradeoffs between ride comfort and road holding in passive suspensions [1-2]. The desired suspension system has to suppress the vehicle body displacement and acceleration together while providing adequate suspension deflection to maintain road holding. Active suspension systems have great potential to achieve these achievement goals. [3-5].

In this study, a new fuzzy logic approach is proposed in order to provide the suppression of vehicle body bounce and acceleration using active suspension system. The controller is applied on a quarter vehicle model in order to indicate the performance of the proposed controller comparing with passive case.

2. Quarter Vehicle Model

Vertical dynamics of a vehicle can be analyzed by quarter vehicle model shown in Figure 1 [6-7]. The model has two degrees of freedom which are the wheel-axle and body bounces. \( m_1 \) and \( m_2 \) are the wheel-axle and body masses, respectively. Wheel and suspension spring stiffnesses are denoted as \( k_1 \) and \( k_2 \), respectively. \( b_2 \) is damping coefficient of viscous damper and \( u \) corresponds to the control force that is produced by the actuator. \( y_0 \) is the road profile changing by time which is to wheel. \( y_1 \) and \( y_2 \) are the absolute displacements of the unsprung and sprung masses respectively.

![Fig. 1 Quarter vehicle model.](image)

Equations of motion for the quarter car model are given below:

\[
m_1\dddot{y}_1 + b_2(\dddot{y}_1 - \dddot{y}_2) + k_2(y_1 - y_2) + k_1(y_1 - y_0) = -u \tag{1}
\]

\[
m_2\dddot{y}_2 + b_2(\dddot{y}_2 - \dddot{y}_1) + k_2(y_2 - y_1) = u \tag{2}
\]

In this study, the quarter car model is subjected to the road input as shown in Figure 2 and vehicle model vibrates as it passes over the road profile with the constant velocity \( V \) at first second of its travel. For the given numerical parameters in Table 1, both uncontrolled and controlled cases are computed.

![Fig. 2 Road profile.](image)

| Table 1: Numerical parameters of the quarter vehicle model. |
|-----------------|-------|-------|
| Parameter       | Value | SI Unit |
| \( m_1 \)       | 36    | kg     |
| \( m_2 \)       | 240   | kg     |
| \( b_2 \)       | 980   | Ns/m   |
| \( k_1 \)       | 160000| N/m    |
| \( k_2 \)       | 16000 | N/m    |
| \( V \)         | 72    | Km/h   |
| \( h \)         | 0.035 | m      |

3. Fuzzy Proportional Derivative Controller

Fuzzy logic theory was first presented by Zadeh [8]. Fuzzy logic control provides ability to use the experience of vehicle suspension system experts. In proposed fuzzy proportional derivative controller, the gains are varied by time while classical proportional derivative controller includes constant gains. Each controller gain is calculated by a fuzzy logic unit. In figure 3 representative unit is shown with a single input - single output relation.

![Fig. 3 Fuzzy logic input-output representation.](image)
Time varied gains of fuzzy PD are obtained from two fuzzy logic units that are for proportional and derivative gains. The input is the related variable and the output is the related variable gain of the proposed controller. SF is the related scaling factor. In Table 2, the input-output relations are given for the related terms of proposed fuzzy PD controller. Actuator control force computed from the proposed fuzzy PD controller is the sum of these terms and is obtained by equation (3). Error is also defined in equation (4).

\[ u = K_{fp} e + K_{id} \frac{de}{dt} \]  
\[ e = y_0 - y_1 \]

Table 2: Fuzzy logic input-output relation.

<table>
<thead>
<tr>
<th>Input</th>
<th>Scaling Factor (SF)</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>PSF</td>
<td></td>
</tr>
<tr>
<td>( \frac{de}{dt} )</td>
<td>DSF</td>
<td></td>
</tr>
</tbody>
</table>

For each fuzzy logic unit of the proposed controller, Mamdani type fuzzy inference with triangular membership functions is utilized and centroid method is used for defuzzification. Fuzzy rule base is very simple and given in Table 3. It involves the same rules for each fuzzy logic unit.

Table 3: Fuzzy logic input-output relation.

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td></td>
</tr>
<tr>
<td>( \frac{de}{dt} )</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S</th>
<th>SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>MG</td>
</tr>
<tr>
<td>B</td>
<td>BG</td>
</tr>
</tbody>
</table>

- If input is small (S) then output gain is small (SG)
- If input is medium (M) then output gain is medium (MG)
- If input is big (B) then output gain is big (BG)

4. Simulation Results

Passive and active suspension system comparisons are computed as it is mentioned in section 2. Both cases are evaluated by time responses of body bounce, acceleration, suspension deflection and control force.

In Figure 4, the vehicle body overshoots the height of the road profile after it reaches over the obstacle in passive suspension case that is denoted as no control in the figure legend. If the active suspension case is considered for the proposed controller; Fuzzy PD, the vehicle body settles on its steady state value very smoothly as seen in the same figure.

![Figure 4 Comparison of body bounce responses.](image)

Fig. 4 Comparison of body bounce responses.

The body acceleration is also decreased by the proposed control strategy and acceleration oscillations have declined rapidly as seen in Figure 5.

![Figure 5 Comparison of body acceleration responses.](image)

Fig. 5 Comparison of body acceleration responses.

There isn’t any permanent deflection in suspension for proposed controller case in figure 6. It is seen that the suspension system gets back to its original position after reaching to the top of the obstacle. Therefore, in both cases, the suspension deflection reaches to zero as the vehicle body settles seen in Figure 4.

![Figure 6 Comparison of suspension deflection responses.](image)

Fig. 6 Comparison of suspension deflection responses.

In Figure 4, the vehicle body overshoots the height of the road profile after it reaches over the obstacle in passive suspension case that is denoted as no control in the figure legend. If the active suspension case is considered for the proposed controller; Fuzzy PD, the vehicle body settles on its steady state value very smoothly as seen in the same figure.
Control force given in Figure 7 acts on both vehicle body and wheel-axle masses simultaneously. Actuator force is saturated at 500 N during computations. This situation is seen as the truncation of force value at ±500 N in control force diagram. Actuator force is also reaches to zero as the vehicle body settles seen in Figure 4.

5. Conclusion

Proportional and derivative gains varied by two single input-single output fuzzy logic controller is proposed in this study in order to reach to the suspension system objectives that aim providing ride comfort without any suspension working space degeneration. Time responses demonstrate that the vehicle body settles smoothly with decreasing body acceleration and preserving suspension working space. The results indicate that the proposed controller exhibits promising behavior.

References

VIBRATION CHARACTERISTICS OF QUARTER CAR SEMI-ACTIVE SUSPENSION MODEL - NUMERICAL SIMULATIONS AND INDOOR TESTING

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Abstract: This paper describes the results of numerical simulations and laboratory experiments of quarter car semi-active suspension model. Elastic characteristic of the coil spring and damping characteristics of the shock absorber in various operating modes are determinate. The amplitude-frequency characteristics and transfer function of the system with various damping coefficient are obtained. The results can be used to design semi-active suspension control strategy for improving ride comfort and road holding of ground vehicles.

Keywords: VEHICLE, SEMI-ACTIVE SUSPENSION, DAMPING, QUARTER CAR MODEL, RIDE COMFORT

1. Introduction

Automotive suspension there is many conflicting requirements. The suspension characteristics must provide good comfort to passengers when driving on uneven road and at the same time good stability when cornering and braking. Furthermore, it is necessary to ensure optimum contact between the wheels and the road under different driving conditions to achieve maximum safety. Passive suspension used in most modern cars don't provide great opportunities for these conflicting requirements and applying controlled suspension with variable characteristics increase.

By using mechatronic systems with active hydraulic or electric actuators and feedback control is possible to realize an active suspension which ensures optimum performance in all ride modes [5]. But such type of suspension is more complicated and more expensive than passive, has a high energy consumption and low reliability. Compromise between passive and active is a semi-active suspension, also known as suspension with active damping. This type of suspension consists of a hydraulic controlled damper with variable coefficient of damping and passive elastic element - usually a metal spring. It has reliability close to that of the passive, but offers adaptability of active suspension, with much lower power consumption [3, 10]. Damping characteristics are changed by changing the passage section of the throttling orifice or by changing the viscosity of the hydraulic fluid.

In order to create an algorithm for optimal control of semi-active suspension for various modes of ride and different input disturbance first necessary should to determine the characteristics of its components - springs and adjustable dampers, and vibration characteristics of sprung and unsprung masses.

In this regard, the objective of this publication is the first with the help of laboratory experiments to determine the characteristics of the elements of the suspension and the second using numerical simulations, computer modeling and laboratory experiments on real physical model of the quarter car to determine its vibration characteristics.

2. Spring and damping characteristics

2.1. Spring characteristic

The spring stiffness characteristic has been received on the electro-hydraulic test bench shown in Fig. 1. The test bench is equipped with a force sensor and displacement sensor.

Analysis of the characteristic (Fig. 2) shows that in the separate points, the coefficient of elasticity is obtained between 19,5 and 20,5 kN/m i.e. it can be considered linear. The average value of the spring ratio on five points:

\[ c = \frac{F_s}{z} = 20 \text{ kN/m} \]

Fig. 1. Spring characteristic test bench.

Fig. 2. Spring stiffness characteristic.

2.2. Shock absorber characteristics

To obtain force-displacement and force-velocity characteristics of the shock absorber was used electro-mechanical shock tester, make from Intercomp®, model Shock Dyno - Hi Speed (Fig. 3).

Fig. 3. Shock absorbers tester:
1. Adjustable shock absorber; 2. Shock tester;
3. Stabilized DC power supply, U = 12 V; 4. Board with a set of switchable resistors; 5. Laptop.
The stand is factory equipped with displacement sensor, force sensor as well as analog-digital device for collecting data type USB-6009 DAQ from National Instruments®. Visualization and recording the shock absorber characteristics was done using a laptop with special software. The methodology for obtaining the characteristics is described in detail in work [8].

Fig. 4 shows the characteristics of the shock absorber tests at different values of current flowing through the solenoid coil (Is). The calculation damping coefficient of the shock absorber is

\[ \beta = \frac{F_{av}}{v} \]

Where \( F_{av} \) and \( F_c \) are respectively the resistance forces of the shock absorber during compression and rebound, N.

Asymmetry ratio is:

\[ k_a = \frac{F_c}{F_r} \]

The parameters of the shock absorber, when the piston speed is \( v = 0,52 \text{ m/s} \) and different amperage are shown in Table 1.

\[ \begin{array}{cccc}
I_c \text{ A} & F_{av}, \text{ N} & \beta, (\text{N.s/m}) & k_a, -
\hline
0,85 & 1425 & 2740 & 1,7 \\
1,30 & 2025 & 3895 & 2,2 \\
1,55 & 2150 & 4135 & 2,3 \\
1,80 & 2475 & 4760 & 2,4 \\
2,00 & 2575 & 4950 & 2,4 \\
\end{array} \]

3. Mechano-mathematical quarter car model

Ride comfort of the car and its operational safety is largely determined by the characteristics of the suspension [9]. Key indicator determining the comfort of motion is the RMS value of the vertical acceleration of the sprung masses \( \sigma_z \). As additional indicators are used the RMS value of maximum vertical acceleration \( \pm z_{max} \).

To identify these indicators and set at the stage of designing the car it needs to be represented by its mechano-mathematical model. For the modeling of the vehicle vertical oscillations, the most commonly used models shown in Fig. 1. The simplest model is the one with 1 degree of freedom (Fig. 1, a). It takes account unsprung mass \( m_c \) acting on a one wheel (1/4 of the car mass).

The calculation damping coefficient of the shock absorber \( \beta \), is obtained as the arithmetic average of the resistive force of the shock absorber \( F_{av} \), divided by the velocity of the piston, which in this case is 0,52 m/s:

\[ \beta = \frac{F_{av}}{v} \]

\[ F_{av} = \frac{F_c + F_r}{2} \]

More complex is dual mass plane model with two degrees of freedom (Fig. 1, b). It consists of two bodies – sprung mass \( m_c \) and unsprung mass \( m_c \), and two elastic elements \( c_e \) and \( c_e \), representing respectively the elasticity of the main elastic element and the tire elasticity. Dissipative elements are \( \beta \) and \( \beta \), and represent the main dissipative elements (dampers) and tire dissipation. Through this model we receive results for the characteristics of the sprung and unsprung masses.

The basis of the method is Lagrange equation of the second order:

\[ \frac{d}{dt} \left( \frac{\partial \Pi}{\partial \dot{q}_i} \right) - \frac{\partial \Pi}{\partial q_i} + \left( \frac{\partial R}{\partial \dot{q}_i} \right) = \dot{Q} \]

wherein T and \( \Pi \) are the kinetic and potential energy of the system;

\( R \) – Rayleigh dissipation function;

\( \dot{Q} \), \( \dot{\dot{Q}} \) - vector of generalized coordinates and velocities;

\( \dot{Q} \) – kinematic disturbance;

\( t \) – time.

For the model of Fig. 1, a) generalized coordinate and it derivatives are:

\[ q = z, \dot{q} = \dot{z}, \ddot{q} = \ddot{z} \].
Differential equation describing the vibration of the system is:

\[ m\ddot{z} + \beta \dot{z} + cz = \beta q + cq \]

Apply the transformation of Laplace with zero initial conditions and receive operator images of equation:

\[ (mp^2 + \beta p + c)Z(p) - (\beta p + c)Z_s(p) = (\beta p + c)Q(p) \]

where \( Z(p) \) and \( Q(p) \) are the Laplace transforms (images) of the functions \( z(t) \) and \( q(t) \); \( p \) - complex variable.

It is known that the transfer function of a linear system is the ratio of the Laplacian image to the output variable to the Laplacian image for the input variable, with zero initial conditions [1]. Then the transfer function of the displacements of the sprung and unsprung masses of the system of Fig. 1, a) is given:

\[ W_s(p) = \frac{Z(p)}{Q(p)} = \frac{\beta p + c}{mp^2 + \beta p + c} \]

The term transfer function is closely related to the term frequency response (amplitude-phase characteristic [1]). Frequency response of a linear dynamic system is called the transfer function for purely imaginary values of the argument \( p \), i.e. in case of \( p = i\nu \), where \( i \) is the imaginary unit, and \( \nu \) is the frequency in rad/s. Then the frequency characteristics are:

\[ W_s(i\nu) = \frac{Z(i\nu)}{Q(i\nu)} = \frac{\beta \nu + c}{m\nu^2 + \beta \nu + c} \]

Spectral densities of the displacements and accelerations of the sprung masses are:

\[ S_z(v) = \nu^2 |W_s(i\nu)|^2 S_q(v) \]
\[ S_q(v) = \nu^2 |W_s(i\nu)|^2 S_z(v) \]

where \( S_q(v) \) is the spectral density of the input disturbance.

For the model of Fig. 1 b) generalized coordinates and their derivatives are:

\[ \{q\} = \begin{bmatrix} z \\ \dot{z} \\ \ddot{z} \end{bmatrix} ; \quad \{\dot{q}\} = \begin{bmatrix} \dot{z} \\ \ddot{z} \end{bmatrix} ; \quad \{\ddot{q}\} = \begin{bmatrix} \ddot{z} \end{bmatrix} \]

Differential equations describing the oscillations of the system are:

\[ m\dddot{z} + \beta \ddot{z} + cz = c\dot{q} + \beta \ddot{q} \]

After detecting parentheses members are grouped as follows:

\[ (mp^2 + \beta p + c)Z(p) - (\beta p + c)Z_s(p) = (\beta p + c)Q(p) \]

Apply the transformation of Laplace with zero initial conditions and operators receive images of equations:

\[ (mp^2 + \beta p + c)Z(p) - (\beta p + c)Z_s(p) = (\beta p + c)Q(p) \]

Then the transfer function of the displacements of the sprung and unsprung masses of the system of Fig. 1, b) as follows:

\[ W_s(p) = \frac{Z(p)}{Q(p)} \quad W_u(p) = \frac{Z_u(p)}{Q(p)} \]

To solve the system (1) using the formulas of Kramer for solving systems of linear equations can be written:

\[ Z(p) = \frac{\Delta_s}{\Delta} \quad Z_s(p) = \frac{\Delta_s}{\Delta} \]

where \( \Delta \) is the main determinant;
\( \Delta_s \) - determinant obtained from \( \Delta \), by replacing the column of the coefficients before \( Z(p) \) with the column of free members (right parts of equations);
\( \Delta_s \) - determinant obtained from \( \Delta \), by replacing the column of the coefficients before \( Z_s(p) \) with the column of free members.

Determinants are the following:

\[ \Delta = \begin{vmatrix} mp^2 + \beta p + c & -(\beta p + c) \\ -(\beta p + c) & (m, p^2 + (\beta + \beta_p) p + c + c) \end{vmatrix} \]

\[ \Delta_s = \begin{vmatrix} \beta p + c & 0 \\ 0 & (\beta p + c) \end{vmatrix} \]

For the transfer functions are obtained:

\[ W_s(p) = \frac{Z(p)}{Q(p)} = \frac{(\beta p + c)(\beta p + c)}{(mp^2 + \beta p + c)(m, p^2 + (\beta + \beta_p) p + c + c) - (\beta p + c)^2} \]

\[ W_u(p) = \frac{Z_u(p)}{Q(p)} = \frac{(mp^2 + \beta p + c)(\beta p + c)}{(mp^2 + \beta p + c)(m, p^2 + (\beta + \beta_p) p + c + c) - (\beta p + c)^2} \]

Then the frequency characteristics are:

\[ W_s(i\nu) = \frac{Z(i\nu)}{Q(i\nu)} \quad W_u(i\nu) = \frac{Z_u(i\nu)}{Q(i\nu)} \]

Spectral densities of the displacements and accelerations of the sprung masses are:

\[ S_z(v) = \nu^2 |W_s(i\nu)|^2 S_q(v) \]
\[ S_q(v) = \nu^2 |W_s(i\nu)|^2 S_z(v) \]

For the unsprung masses:

\[ S_z(v) = \nu^2 |W_u(i\nu)|^2 S_q(v) \]
\[ S_q(v) = \nu^2 |W_u(i\nu)|^2 S_z(v) \]

4. Numerical experiments

4.1. 1DOF model

Numerical experiments were conducted in MATLAB. The spring ratio of the spring is obtained in section 2.1 - \( c = 20 \text{ kN/m} \). Damping parameters are given in Table 1, sprung mass \( m \) varies in the range of 100-400 kg.
Fig. 7. Oscillogram of 1DOF model damping oscillations at \( m = 400 \) kg, and different damping coefficient \( \beta \).

Fig. 8. Amplitude-frequency and a phase-frequency response of 1DOF model at \( m = 400 \) kg, and different coefficients \( \beta \).

4.2. 2DOF model

Unsprung mass is \( m_t = 30 \) kg, tire spring ratio \( c_t = 150 \) kN/m, tire damping \( \beta_t = 50 \) N.s/m. The other parameters are as 1DOF model.

Fig. 9. Amplitude-frequency and a phase-frequency response of 2DOF model at \( m = 400 \) kg, and different coefficients \( \beta \).

Peak of frequency response are at frequencies close to the natural frequency of sprung and unsprung masses.

In a study of random vibrations spectral density of road bumps is set with the [4]:

\[
S_v(v) = \frac{0.000203 \cdot 0.75 \cdot 1.5 \cdot \vartheta}{\pi} \frac{1}{v^2 + (1.5 \cdot \vartheta)^2}
\]

where \( v \) and \( \vartheta \) are respectively the frequency and velocity of the transport unit.

Spectral density of the calculations in vehicle speed 5 m/s are shown below:

Fig. 10. Spectral density of acceleration of the sprung mass at different values of \( \beta \).

Fig. 11. Spectral density of acceleration of the unsprung masses at different values of \( \beta \).

Increasing the damping coefficient of the shock absorber increase the accelerations of the sprung mass in the resonance and the after resonant region, and slightly reduces the acceleration before the region of resonant frequency.

By accelerations of unsprung masses noticed a significant reduction in high rates of damping to given frequency range. The most obvious is the reduction of the accelerations at the resonant frequency of these masses. Small accelerations testify to small intensity of vibration of the wheels. This is expressed conflicting demands on damping and the need to reduce the coefficient \( \beta \) for maximum comfort and it increasing when we need maximum contact between tire and the road.

5. Suspension indoor testing

Fig. 12. Test bench for obtaining vibration characteristics with a load of 100 kg (a) and 160 kg (b).
Fig. 13. Acceleration of the sprung mass and the relative displacement of vibration platform of the test bench with load of 100 kg and a growing frequency from 1 to 20 Hz and decreasing from 20 to 1 Hz.

Fig. 14. Acceleration of the vibration platform of the test bench, acceleration of the sprung mass and the relative displacement of platform with load of 100 kg and frequency of 3 Hz. The coefficient β changes from 2740 to 4950 (app. 10 s) and from 4950 to 2740 N.s/m (app. 20 s).

Fig. 15. Acceleration of the vibration platform of the test bench, acceleration of the sprung mass and the relative displacement of platform with load of 160 kg and frequency of 8 Hz. The coefficient β changes from 2740 to 4950 (app. 10 s) and from 4950 to 2740 N.s/m (app. 20 s).

Fig. 16. Acceleration of the vibration platform ($a_v$) and sprung mass ($a_z$), at frequency 8 Hz, $m=160$ kg and amplitude $q_0=4$ mm, numerical modeling (a) and laboratory experiment (b).

Analysis of the results indicates that the system is linear. Since the gradual increase in the frequency of interference and consequent reduction, the maximum amplitude of resonant modes is approximately equal (Fig. 13). On the same figure is significantly shifting the zero line of oscillations in after resonance mode. It is due to the gravity of the sprung mass down, due to the asymmetric damping. As a result, the dynamic vertical coordinate of the sprung masses (car body) is reduced and increases the likelihood of impact of the suspension travel of the vehicle and of appearance so-called ”jerk” in the suspension, which is felt by the driver and passengers in the car as a hard impact when ride through bumps.

Fig. 14 and Fig. 15 show changes that occur in the same size and frequency of disturbance and changing the resistance coefficient of the shock absorber. Unsprung mass acceleration variation is more significant at high frequencies and observes the ”pull” of unsprung mass down at a high coefficient of damping, again more noticeable at high frequencies of disturbance. At 8 Hz (Fig. 15) its value is about 1.5 cm.

Fig. 16 shows a better comparability of results of numerical and laboratory experiments using deterministic sinusoidal disturbance.

5. Conclusion

The considered models and presented laboratory equipment, enable to determine series of vibration characteristics of semi-active suspension. Results for waveforms for free damped oscillations amplitude- and phase-frequency characteristics, spectral density of acceleration and other characteristics of the forced vibrations with deterministic or random nature are received. The results of numerical modeling have good compatibility with those of laboratory experiments and can be used to compile algorithms and control strategies of semi-active suspension to improve the comfort and road holding of the road vehicles.

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CALCULATION ALGORITHM FOR PEDESTRIAN GREEN TIME

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Abstract: Places of crossing the roadway by pedestrians, regulated by traffic lights, provided largely safe passage. In these cases attached times of individual signals have to guarantee minimum delay of both streams. The paper presents a calculation algorithm for pedestrian green time according to the intensity of traffic flows and pedestrian flows in certain road conditions.

Keywords: TRAFFIC LIGHTS, PEDESTRIAN FLOWS, TRAFFIC FLOWS

1. Introduction

The problems of pedestrian and traffic movements must be considered comprehensively. The increase in traffic volume leads to an increase in pedestrian volume, which adds to the conflict [1]. It instigates many problems with traffic management at pedestrian crossing places. In these cases it is necessary to analyze the options for passage of pedestrians and choose the one that provides the least waiting time of vehicles and pedestrians.

2. Prerequisites and means for solving the problem

Signalized pedestrian crossings are used in certain conditions. The lengths of the green signals for pedestrians and vehicles depend on the intensity of pedestrian and traffic flows. To achieve optimal lengths of these signals, an algorithm for their calculation has been developed.

The theoretical formulation is presented for a signalized pedestrian crossing.

The input data for the algorithm are:
- Width of the walkway (Bw), m;
- Length of necessary space for a pedestrian (Lp) – it is assumed to be 0.75 m;
- Width of necessary space for a pedestrian (Bp) – it is assumed to be 0.75 m;
- Width of roadway (W), m;
- Length of the car (Lc) – it is assumed to be 5 m;
- Average speed of vehicles at the crossing (Vc) in m/s – it depends on the duration of the green signal and the length of the queue;
- Average speed of pedestrians when crossing the roadway (Vp) in m/s – it is determined according to the speed of the prevailing gender and age of the pedestrians;
- Intensity of traffic flows (I), veh/s [2];
- Intensity of pedestrian flows (Ip), ped/s;
- Maximum cycle length (tc) in seconds – it is determined according to the existing traffic conditions, the need of traffic light coordination of nearby intersections, regulations, etc.

3. Results and discussion

The algorithm requires initial values for green time for vehicles (tg) and pedestrians (tp) for determining the initial value for the cycle length (tc) that will be subsequently optimized. Thus the condition that the calculated values should guarantee lack of queues of vehicles and/or pedestrians is met.

\[ t_c = t_g^e + t_p^e + t_y + \Delta t + t_y, s \] (1)

Where:
- \( t_g^e \) - The time required for a person to traverse the roadway, s;
- \( \Delta t \) - The time from the beginning of the red signal for vehicles to the beginning of the green signal for pedestrians, s;
- \( t_y \) - Yellow signal duration after green time for vehicles (it is assumed to be 3 seconds at a maximum authorized speed of 50 km/h);
- \( t_y \) - Yellow signal duration in combination with red signal for vehicles (it is assumed to be 2 seconds at a maximum authorized speed of 50 km/h).

The time required for a person to traverse the roadway guarantees that the last pedestrian to step on the crossing at the end of the green signal for pedestrians will manage to cross the roadway before the beginning of the green signal for vehicles. It is equal to the time required for crossing the roadway:

\[ t_p = \frac{B_w}{V_p}, s \] (2)

The number of arriving pedestrians (P) and vehicles (A) during the cycle duration is determined using the following formula where the calculated values include pedestrians and vehicles arriving from both directions of movement:

\[ P = t_c \times I_p^a \text{ ped} \] (3)

\[ A = t_c \times I_p^a \text{ veh} \] (4)

The values for pedestrian crossing time (tp) and vehicle crossing time (t) are calculated. The pedestrian crossing time is calculated according to (2), while the vehicle-crossing time is calculated as follows:

\[ t_p = \frac{S_c}{V_c}, s \] (5)

Where:
- \( S_c \) - The distance traveled by a car passing through the crossing – it is equal to the sum of the width of the crossing, the length of the car and the distance from the stop line to the crossing.

When traversing the crossing, it is assumed that the pedestrians move next to each other and one after the other according to the required space for one person.

\[ N_{ww} = \frac{B_w}{B_p}, \text{ ped} \] (6)
Where:

\( N_{ww} \) - Number of pedestrians who can move next to each other along the crossing.

The time after which the next group of pedestrians in a row can start walking \((t_b)\) again depends on the required area for uninterrupted walking along the crossing and on the pedestrian speed. It is determined as follows:

\[
I_b = \frac{L_p}{V_p}, \text{s} \quad (7)
\]

The number of pedestrian groups walking next to each other who can traverse the crossing during the green signal \((G)\) is calculated with the help of the following formula:

\[
G = \frac{t_p^g}{I_b}, \text{ped} \quad (8)
\]

The calculated values allow us to determine the number of vehicles \((A_p)\) and pedestrians \((P_p)\) that pass during the cycle length:

\[
A_p = \frac{t_c^g}{I_p}, \text{veh} \quad (9)
\]

\[
P_p = G \times N_{ww}, \text{ped} \quad (10)
\]

It can be subsequently determined whether there are remaining vehicles \((Q_c)\) and pedestrians \((Q_p)\) in queue. This is done by analyzing the differences between the number of arriving and passing vehicles or pedestrians for a traffic light cycle, respectively. If in both cases, there are no queues \((Q_c \leq 0 \text{ and } Q_p \leq 0)\), the green signal lengths for vehicles and for pedestrians are optimal.

In case there is an accumulation of queues \((Q_c > 0 \text{ and/or } Q_p > 0)\), then the green signal lengths for vehicles or for pedestrians are increased by a certain step, respectively. Calculations in the same sequence are performed until values for the queues are reached. This procedure is repeated until both flows are queue-free. A generalized block diagram of the calculation algorithm for pedestrian green time is shown in Fig. 1.

In case there is an accumulation of vehicle and/or pedestrian queues even after reaching the end of the cycle \((t_c^\text{max})\), we apply the values for green signal lengths where the queue values are the smallest. In cases where the queues are very long and it is difficult for vehicles and pedestrians to pass, other solutions have to be sought for in order for vehicles and pedestrians to cross the relevant section of road.

4. Conclusions

The presented algorithm for calculating pedestrian green time has the following major advantages:

1. It can be used for pedestrian movement management in cases where there are technical resources for reporting information about the intensity of traffic and pedestrian flows.
2. It can be used not only for isolated pedestrian crossings.
3. The results it produces can be used to calculate cycle lengths for signalized intersections more accurately.

References


THE NOISE FROM VEHICLES AND TRANSPORT FLOW

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Abstract: Increases in road traffic lead to the expansion of areas of the acoustic discomfort, and the noises from vehicles acquire social importance. The noise as a set of sounds is characterized qualitatively and quantitatively by two main indicators: the sound pressure or intensity level, which have different effect on the human body. In addition, in terms of the effect on the human body, the preference is given to the noise equivalent level. The study of the noise equivalent level can be carried out in two ways. The first one consists in fact that at a given moment of time, if at any point in space, there are summarized the noise level or sound energy intensity from all radiation sources, but another way implies summarizing the selected sound energy sources during a certain time period. So, in order to determine the noise equivalent level of one vehicle during that time period, which is required for passing a certain section, it is necessary to know those laws, which characterize traffic conditions and the calculated changes of the noise level in these conditions.

KEY WORDS: TRANSPORT FLOW; TRAFFIC CONDITION; NOISE LEVEL; SOUND ENERGY.

1. Introduction

In the airspace, human being is capable of perceiving sound vibrations in a wide range: with power – $10^{-12}$-1 W; frequency - 20-20000 Hz. However, sound carries not only useful information. Orderless and highly-intensive sound causes fatigue and performance decrement, but its long-term effect causes the pathological changes in the internal organs.

Vehicle noise is one of significant parameters of the environmental pollution and its control is very important for specialists. Transport flow generates 60-80% of sound affecting human health. In the conditions of growing scale of car traffic, the areas of the acoustic discomfort increase considerably and vehicle noise gains a social significance.

In all vehicles, including a moving car, energy conversion is accompanied by the acoustic emission into environment. One of such channels of this emission is represented by sound waves. They represent an oscillatory motion of wave of the elastic medium. The sources of a moving car are surfaces of the engine installation, intake and exhaust systems, surfaces of the transmission systems. Noise is also generated when interacting a moving car with an air flow, tires with road a road surface, by the oscillations of the suspension components and a car trunk, which are caused by the road irregularities, and so on.

2. Preconditions and means for resolving the problem

To describe the source of the emission, there is used full sound power $W$, which is emitted into into surrounding hemisphere

$$W = \frac{1}{2} \pi \rho C r^2$$

$r$ – a radius of hemispher, is measured in unit of meter.

The values of sound pressure, sound intensity and sound power vary within a wide range. For example, the lowest sound pressure, which are perceptible to the organs of hearing, is $2 \times 10^{-5}$ N/m², at the same time, it can reach $2 \times 10^4$ N/m². The absolute values of these parameters are not convenient for using, since the range of variations is too wide. That is why it is customary to use the relative figures, which are expressed in the logarithmic units, decibels (dB). So, in order to prevent noise, there are accepted the relative figures, such as the unit of the comparing parameters – to sound pressure level, sound intensity level and to sound power level. The limiting sound pressure is accepted as a comparing unit of sound pressure, which is equal to $2 \times 10^{-5}$ N/m²; this value has been standardized. As a result, we came to a point where we accept that the mentioned relative figures take absolute values, since they identically characterize absolute values of sound pressure and sound intensity.

Sound intensity level

$$L_i = 10 \log \frac{I}{I_0},$$

where $I_0$ – a sound limit value, when frequency $f=1000$ Hz, $I_0 = 10^{-12}$ W/m².

Such sound intensity corresponds with the limiting sound pressure $P_0=2 \times 10^{-5}$ N/m². The multiplier 10 is used to obtain smaller units of noise – one tenth of a logarithm.

Sound pressure level

$$L_p = 10 \log \frac{P^2}{P_0^2} = 20 \log \frac{P}{P_0} = 10 \log \frac{I}{I_0},$$

where $P_0$ – the limiting value of pressure.

Thus, therefore, noise as the totality of sound, is characterized quantitatively and qualitatively, consequently, by two basic parameters: the level of sound pressure or intensity, i.e. the totality of sound frequency, which generates noise. Its effects on an organism are different. In addition, from the objective point of view, regarding the health, preference is given to the noise equivalent level $L_{eq}$. It is an equivalent-continuous noise level, during which, in a given fraction of time, there is released the same energy as with variable noise, in the same fraction of time.

$$L_{eq} = 10 \log \left[ \frac{1}{4} \int_0^T 10^{0.1L_i} \,dt \right]$$

Thus, we came to a point where we accept that the effect of noise generated by transport flow is estimated by the value of the equivalent level $L_{eq}$ dB and frequency corrected by $A$ characteristic.

Modeling of noise from one car involves serious difficulties, since state of the atmpspher is unstable by nature. Density, temperature, wind and humidity are neve constant in a given volume and time. When going through the atmosphere, sound waves are exposed to these variable parameters, if the propagation distance of sound wave is long.

Thus, sound level (in decibels) is an indicator, which has been obtained by the ratio of sound intensity logarithm to sound limit value. A minimum sound intensity, which is perceptible to a man with good ears is $I_0 = 10^{-12}$ W/m².

Sound level is calculated according to the following formula:

$$L = 10 \log \frac{I}{I_0},$$

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Transformation of this expression is possible, if we insert the value
\[
L_0 = 10^{-12}
\]

\[
L = 10 \log I - 10 \log L_0 = 10 \log I + 120
\]

If sound level is known, sound intensity would be
\[
I = 10^{0.1 L - 12}
\]

Computational scheme for characteristics of noise generated by transport flow, is designed in the following way. First, there are determined sound indicators of vehicles in the flow. Noises from all vehicles are summarized in accordance with a certain law. The main element of the calculation of transport flow noise is the establishment of the objective laws, which allow for determining noise from each individual car. A sound field of transport flow, from the acoustic positions, is a field, which is generated by the distribution system of the point-source emitters.

General theory of the emitting system distribution provides principled approaches to the calculation of the emission, when distributing system in various conditions. The basic method is energy summation method. The capacities of energy summation method largely depend on the frequency characteristics of the emitter [1].

The picture of a quite complex interference field obtained with a fixed frequency, largely depends on the coordinates of a point and on frequency, and varies many times with slight variations in initial conditions, but, in fact, we do not notice such variations, because clear interference picture is obtained only with pure sounds.

The summation procedure itself and study of noise equivalent level can be carried out in two ways. The first one consists in fact that at a given moment of time, at any point in space, there are summarized the noise level or sound energy intensity from all emission sources.

In this case, the aggregate instantaneous values are to be taken for system noise
\[
L_m = 10 \log \sum_{i=1}^{N} 10^{0.1 L_i - 12} + 120,
\]

where \( N \) – the number of noise sources. Then, the noise equivalent level is calculated.

Also, during the calculations the second method of energy summation. This means summation of the sources of selected sound energy during the \( T \) time.

\[
I_n = \sum_{i=1}^{N} I_{in},
\]

where \( I_n \) and \( I_{in} \) – sound energy intensity for transport flow and \( i \)-th car.

The sound equivalent level of transport flow \( N \) during the intensive movement
\[
L_e = 10 \log \sum_{i=1}^{N} I_{i0} + 120
\]

To determine sound equivalent level of the \( i \)-th vehicle, which moves within transport flow, for the observer staying on 7.5 m from traffic lane, the following formula can be considered

\[
W = I (2 \pi r)^2 = 2 \pi r^2 \frac{P^2}{\varrho C}
\]

Let’s assume that the vehicle is an omnidirectional point-source power. \( W_i \), which is located in a free semi-space, we can express its sound intensity at any \( r \) distance by, as \( I(r) = \), obtain, for a given condition, the calculating expression \( I_\theta(T) = I_{i0} \) on 7.5 m from traffic lane

\[
W_i = I(r) 2\pi r_i^2 = I_{i0} 2\pi (7.5)^2
\]

or

\[
I(r) = 56.25 I_{i0} / r_i^2
\]

Noise level from the emission source at any distance

\[
L_0 = 10 \log \left( \frac{56.25^2 I_{i0}}{120} \right) = 10 \log I_{i0} - 20 \log \frac{r_i}{7.5}
\]

Therefore, during the process of car movement, the distance from it to a measuring point varies in accordance with the patterns of this movement. Fig. 1 illustrates the distance from the observation point to the emission source is

\[
r_i = \sqrt{x_i^2 + y^2},
\]

where \( x_i \) – a current coordinate of a car \( x_i = f(t) \); \( y \) – the distance from the measuring point to traffic lane.

\[
\text{Fig.1. Computational scheme for determining the distance to the point of noise.}
\]

The current value of sound energy intensity at the oberving point

\[
I_i(r) = 56.25 I_{i0} \left( \frac{x_i^2 + y^2}{y_0^2} \right)
\]

To determine the “integral intensity”, which at point \( O \) comes on the section, or during the \( T \) time required for passing this section, which is identical from physical standpoint, it is necessary to integrate the expression \( I_i(r) \) by distance or time

\[
I_{it} = 56.25 \int_{x_1}^{x_2} \frac{I_{i0}}{x_i^2 + y^2} \, dx
\]

The equivalent intensity is derived by dividing the integral intensity by distance or time.

\[
I_{ie} = \frac{I_{it}}{x_1 x_2} = \frac{I_{it}}{T(x_1 x_2)}
\]

The noise equivalent level, when passing through the section, is determined by inserting noise level into the formula \( L_{i0} \)

\[
L_{ie} = 10 \log \frac{I_{ie}}{I_{i0}} = 10 \log I_{ie} + 120
\]

3. Conclusion

Thus and so, in order to determine the noise equivalent level of one vehicle during the time, which is required for passing through a certain section, it is necessary to know those laws, which characterize traffic conditions and the calculating variations of noise level in given traffic conditions.

4. References


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ITS-RELATED ASPECTS OF DEVELOPMENT OF URBAN TRANSPORT SYSTEMS

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ABSTRACT: This article provides an overview of an ITS-related application developed for Urban transport systems in Russia. In today’s society, where the public relies increasingly on the transport network, Russian Federation, as the many other countries, faces tough challenges ahead. From congestion, safety to environmental impact, technology provides a rich variety of options to address existing and future concerns, and Intelligent Transport Systems are at the forefront.

Deregulation of public transport in Russian market places new challenges for national transport companies. There is an increasing need of new service models and operational schemes allowing improved transport offer and competitive advantages. Investments are necessary to optimize the use of transport resources and increase the quality of service for the customers.

Information and communications technologies play a fundamental role to achieve these objectives. This is the case with both flexible transport, where telematics allows to optimize resources and improve mobility services for the customers, and with optimization of regular, line based transport services.

Thereupon, coordinate (position data), time and the navigation support (CTNS) together with telecommunications became a main informational background for automation basic technologies for the Urban transport systems.

KEYWORDS: Automatic Vehicle Location (AVL), Coordinate (position data), time and the navigation support (CTNS), Dispatch control system, Information, Intelligent Transport Systems (ITS), Monitoring system, Satellite navigation, Telecommunications systems, Transport telematics, Urban transport systems.

INTRODUCTION

The exponential growth of satellite navigation devices since the last 10 years supports the opinion expressed then that the use of factory-fitted, PDA or ‘stand-along’ devices demonstrates the public’s interest in minimizing journey times and avoiding travel delay and inconvenience and there are great expectations from the delivery of accurate location based, road user and tolling services.

The importance of secure asset-tracking is self-evident, however, it is essential that minimum standard data concerning security on connectivity and communication are invoked particularly with increased reliance on collecting vast amounts of data over Wireline, WI-Fi, GPRS, Bluetooth and Ethernet connections.

This article provides an overview of a the main Moscow State Automobile and Road Technical University’s scientific and educational activities towards the ITS-related aspects of development of Urban transport systems. The main purpose is providing the scientific background for the following key themes:

- Improving road network management;
- Improving road safety;
- Better travel and traveler information;
- Better public transport on the roads;
- Supporting the efficiency of the road freight industry;
- Reducing negative environmental impacts.

The main aspects, which involved these themes into the Urban transport systems (as the main integrate multiplier) are Video image processing systems, Automatic Vehicle Location (AVL) technology and telecommunications systems and Public transportation Priority Systems.

Video image processing systems for real time traffic data collection processing of images from a video camera for real time estimation of traffic characteristics and data transmission to the control unit, especially in the case of Web interface (which allows provision of online public information for quick inspection of road traffic situation).

Automatic Vehicle Location (AVL) technology and telecommunications systems is a powerful tool for managing fleets of vehicles, from service vehicles, emergency vehicles, and construction equipment, to public transport vehicles (buses and trains). It also is used to track mobile remote assets, such as construction equipment, trailers, and portable power generators. Using an AVL system allows dispatch personnel to evaluate the locations of all vehicles in a fleet.

And, the Public transportation Priority Systems give priority to public transportation such as buses by means of bus lanes, warning vehicles which are illegally running in the bus lane and traffic signal preemption. For the latter, a fleet monitoring and management system, including automated vehicle location capabilities, will be a fundamental element for effective service operation.

The main benefits of such combination of these ITS-related applications are: improve convenience for users, encourage the use of public transportation, ensure on-time bus operation, reduce bus waiting time at intersection, reduce the number of traffic violators driving in a bus lane, ensure bus safety (when making a right turn or merging into traffic out of the bus bay).

CTNS AS THE MAIN PLATFORM FOR ITS-RELATED TRANSPORT TECHNOLOGIES

At the present stage, development of the automated systems in Urban transport in Russia (for example - systems of dispatching management by transport on the basis of satellite navigation) became the real tool for control and the account of performance of transport work, for the full provides definition of places of road accident and emergencies, increase of efficiency at rendering medical aid and evacuation of victims, carrying out of actions of the Ministry of Emergency Measures and mobilization readiness.

In Russia practical use of a wide spectrum of opportunities of satellite navigation for the decision of organizational-technological problems of transport is realized within the Federal target program (FTP) “Global Navigating System”.

In this connection, coordinate (position data), time and the navigation support (CTNS) together with telecommunications became a necessary informational background for automation basic technologies for the transporting passengers and goods by road, including (See fig.1):

a) Automation of dispatching management by passenger transportations (automation dispatching control movement), including Automation of gathering and the account of incomes of passenger carriers (automate data collection, the proceeds);

b) Automation of research and monitoring of volumes of passenger traffic (on passenger route);

c) Automation of informing of passengers (automation inform the transport process).

A global strategy for urban mobility management consists in wide usage of Intelligent Transport System (ITS) and technologies (See fig.2) and it is not less than infrastructure, vehicles and demand management.

To address the solutions of the organization, technological and technical tasks of CTNS in road transport corporate systems, on-board unit’s hardware and software applications should be built on the principles of modular architecture and the need to provide an opportunity to modernize its based on the needs and objectives of carriers.
Intelligent Transport Systems - is a generic term for the integrated application of communications, control and information processing technologies to the transportation system.

ITS covers all modes of transport and considers all elements of the transportation system - the vehicle, the infrastructure, and the driver or user, interacting together dynamically. The overall function of ITS is to improve decision making, often in real time, by transport network controllers and other users, thereby improving the operation of the entire transport system. The definition encompasses a broad array of techniques and approaches that may be achieved through stand-alone technological applications or as enhancements to other transportation strategies.

ITS deployment has much to offer to all of the main groups of stakeholders: National, regional and municipal governments and public authorities; Owners and operators of transport networks (public- and private-sector); Automotive manufacturers; Fleet operators (commercial and public transport); Industry and commerce; Individual travelers.

Governments have a political priority to deliver sustainable and efficient transport. They need to evaluate the benefits of ITS (both nationally and globally) as the basis for long-term investments. ITS methods are policy-neutral, and can be adapted to a range of needs. At national level, governments can pave the way with enabling legislation (e.g. regulations for road user charging) and create frameworks for private-sector involvement, (e.g. via public-private partnerships). At regional and municipal levels, they can implement demand management and
integrated information (inter-modal and multimodal) and payment systems, to encourage intermodal travel.

Operators of road, rail, tram and waterway networks and the associated transport interchanges (from road to rail and transit, and the airports, ports and ferry terminals) can manage their operations with better information and can provide users with safer or more reliable travel conditions. Automotive manufacturers can achieve significant product differentiation and customer loyalty by developing appropriate in-vehicle telematics products.

Vehicle fleet owners can run more cost-effective services and save on energy costs. Businesses can move goods and services more efficiently. Individuals can plan journeys better, enjoy safer travel, avoid delays, and make informed choices between modes. All transport providers and users can enjoy greater security.

Thus, effective automation of the basic technologies in transportation systems is to be based on the use of a specialized on-board unit’s hardware and software to achieve the objectives of CTNS through the use of satellite navigation and the transmission of digital data of the board-control center, and voice communications between the driver and dispatcher (controller).

Relevant ITS services include: Intelligent speed adaptation; Assistance for vulnerable road users; Weather and road condition monitoring and information; Incident detection and warning systems; Collision warning systems; Emergency vehicle priority; Driver monitoring systems; Speed and traffic signal enforcement; Hazardous load monitoring; Cargo screening; Driver vision enhancement systems; Evacuation route signing and priority.

For all transport networks the major problem is congestion, and increasing the efficiency of existing transport systems is a major goal of ITS programs. Congestion can be reduced by instrumenting networks to improve their real-time operation; introducing control systems; managing demand; and encouraging off-peak travel or the use of alternative modes.

Relevant ITS services include:

1) Network Efficiency: Area-wide traffic control; Long-distance traffic management; Rerouting guidance; Variable speed controls; Ramp metering; Incident detection and management; Driver information.

2) Demand management: Access control; Road user charging; Congestion charging.

3) Encouragement of modal shift: Journey planning; Real-time passenger information systems; Bus/tram traffic priority.

Users of urban transportation system need to feel comfortable, confident and secure. Route confirmation, journey time estimates and clear advice on approaching interchanges and connections all play their part. Speed controls, ramp metering, advance incident and congestion warnings, journeys easier and less stressful. Facilities such as multimedia systems that provide both entertainment and navigation can do this too.

ITS relies on a wide range of enabling technologies and functions.

1) Communications: Microwave, short-range radio and infrared-based dedicated short-range communications (DSRC) - used for EFC; commercial vehicle operations (CVO) pre-clearance; Mobile communications - used for real-time travel information; fleet management; emergency response; The Internet - used for real-time travel information; trip planning; traffic images; payment.

2) Geographical Location: Global navigation technology: global navigation satellite systems (GNSS) – GPS (Usa), GLONASS (Russia), Galileo (Europe) - used for satellite-based position finding for automatic vehicle location (AVL); tracking and tracing; distance-based EFC.

3) Geographical Information Systems: Used for location-based databases of transportation networks, location-based services and other features.

4) Data Acquisition and Exchange: Used for real-time traffic management and information.


6) Detection and Classification: Used for traffic management, incident management; compliance; safety; security.

7) In-vehicle Systems: Used for travel information, vehicle control systems, accident avoidance.

8) Digital Mapping: Databases of road and transportation networks stored on digital media using agreed data dictionaries and standardised location referencing. Digital maps are a key building block for ITS; Used for traffic management, traffic information, route guidance, car park management and routing, lorry route monitoring; recreational facilities direction.

### AVL-BASED AUTOMATION OF DISPATCHING MANAGEMENT BY PASSENGER TRANSPORTATIONS FOR URBAN TRANSPORT SYSTEMS

Public transport users also expect high standards of comfort, convenience and service. ITS can provide the real-time passenger information, automated scheduling and priority systems needed to improve public transport. Relevant ITS services include: Real-time traffic and public transport information; Dynamic route guidance; Automatic vehicle location (AVL); Smarter payment systems for toll highway and public transport use.

Examples for passenger transport, grading passenger buses for the movement of more possible on the following tasks: management of the electronic bus route signs in operational switching its traffic to another route; obtaining control centre video into a compartment of a bus driver's signal, or at the request of control system;

Advanced Public Transport Systems (APTS) applications aim to improve the efficiency and user-friendliness of public (collective) transport. They include real-time information systems; fare advice, pre-booking and journey-planning; demand-responsive transport and ride-sharing; and automated scheduling for better fleet management and increased security. All help to position public transport within integrated, multimodal systems that will encourage people to rely less on cars, and so help reduce traffic congestion and environmental pollution.

One way of promoting greater use of public transport is by providing reliable and easily-accessible real-time passenger information (RTPI) - See fig.3-4. Automatic vehicle location (AVL) can drive real-time information systems giving service running and connection times and route advice in-vehicle, at-stop, at home or work, on the street or using other transport modes. Information can be provided via various media including the Internet, interactive information kiosks, text messages to cell phones, voice phone inquiry services and personal digital assistants (PDAs). Enhancements include journey planning, fare options, booking services and 'on-arrival' location and tourist information.

ITS support efficient operation and management of public transport vehicle fleets. On-board AVL continuously transmits data that enables the operator's control centre to monitor individual vehicle's schedule keeping and adjust service intervals to compensate for early or late running. Using GIS-aided Regional multi-screen monitoring, automatic fleet monitoring can also give early warning of maintenance needs and anticipate the risk of vehicle breakdown (See fig. 5).

Door opening/closing detection systems and automated fare collection (AFC) provide operators with valuable passenger data - including loading, journey length, and time of travel - which they can use to evaluate route usage and refine services to meet
passenger demands and roster vehicles and drivers more effectively, and improve financial management.

ITS-based shared and demand responsive transport systems are bridging the gap between private and public transport. Potential users contact a control centre to specify their destination, preferred time of travel, and any special needs.

The centre uses AVL to identify and dispatch the most conveniently-located vehicle, which also carries other passengers on compatible routes. Charges can be billed automatically to accounts. Fleets can consist of public transport vehicles or taxis. Car-pooling, which is being introduced in a number of Russian cities, is a similar concept, with intending users pre-booking vehicles to suit their individual travel needs. It also has urban planning benefits, in that building developers can be required (or choose) to provide fewer parking spaces, so saving land and costs.

Also ITS-related modern EP systems offer major advantages over cash payment for transport and highway operators, their passengers and customers. ETC/EFC is now well developed on expressways, bridges and tunnels across the world.

Smartcards in AFC systems offer public transport operators more flexible ticketing, lower administrative costs, and better management and marketing information; while passengers save time and appreciate the convenience and security of cash-free travel. EPS also offer prospects of interoperability within and across transport modes and systems, using a single, intelligent payment medium.
Public transport vehicles can be given priority over general traffic by integrating their operation into urban traffic control (UTC) systems. AVL enables buses and trams to be identified on the approaches to signalised intersections, where they 'request' the traffic light controller to extend or recall the green phase for long enough to let them through. Detection can be via inductive loops under the road surface, roadside beacons, or satellite-based positioning systems (see fig. 6).

This supplements conventional bus lanes with specially-designed track sections that deter general traffic and speed buses past known congestion points. In mechanical systems, lateral wheels on front wheel mountings guide the bus along raised curbs (relieving the driver of the need to steer). The electronic system is based on an electric cable embedded in the centre of the bus way, with onboard inductive detection that continuously steers the wheels to keep the vehicle centred over the cable. At the end of a bus way section, traffic signal priority gives access to general lanes.
AUTOMATION OF RESEARCH AND MONITORING OF VOLUMES OF PASSENGER TRAFFIC - REAL ITS-RELATED SOLUTION FOR URBAN TRANSPORT SYSTEMS

The development and demand of the AVL-systems of public transport control initiated the further research and development of new telematic systems for public transport such as “Automated System for Monitoring of volumes of passenger traffic (Passenger’s Flows)”. The demand of such system was based on the following factors:

- 50-80% of the inhabitants use the public transport every day.

The load of public transport is 20-50% of rated capacity, while the load at rush-hour is 90-150% of rated capacity. The hardware-software complex of automatic system of research and monitoring of volumes of passenger traffic is intended for replacement of existing manual methods of inspections of volumes of passenger traffic. There are modern means and technologies in the basis of it. Tool means allow to carry out stage-by-stage creation of constantly operating (working) automated system of monitoring of actually executed services on transportation of passengers (See fig.7).

![Fig.7 Automatic system of research and monitoring of volumes of passenger traffic – main levels.](image)

The method which is used at calculation of number of entering and leaving passengers through a door of a vehicle is based on use of tiny gauges of thermal radiation which are mounted above doors of a vehicle (See fig.8).

Gauges register impulses of thermal radiation which each time arises at crossing by the passenger of a zone of measurement of the gauge of the analyzer. The gauge includes passive and active elements. The active component in the gauge consists of the transmitter.

Data obtained from routes collect in constant databases of volumes of passenger traffic, in the further are processed by applied software in the cuts necessary for motor-vehicle pools and city administration (See fig.9-10).

![Fig.8 Technical Principles of automated sum of entering and exiting passengers at each door](image)

The automated analysis of volumes of passenger traffic on lines of routes, on concrete stopping items, on hours of day, days of week, seasons is provided. Following primary goals are solved: Calculation trip and stopping and passenger traffic on surveyed routes; Calculation of characteristics of a volume of passenger traffic on a route; Calculations of a standard set of parameters of the analysis of volumes of passenger traffic (methodology of a “tabulated” method); Formation of data about distribution of
interstopping correspondence of trips of passengers; An estimation of quality of transportations and efficiency of use of a rolling stock.

Each of the data sets which is collected on the route are processed identifying the stations of the public transport and concrete trip. Collected arrays of statistic provide to get the values of a big variety of activities related to a trip, passenger turnover on the stations, the dynamic of the passenger’s flows during a day, an average distance of the trip and passenger turnover during the trip. In particular one of the most urgent activities of transportation is the number of carried passengers per hour. Inconsistency between the plan and fact values gives ground to change the schedule of the public transport and for definition of the required vehicle number per hours during a day (See fig. 9).

A bigger amount of the collected data gives the opportunity to get information of the passengers flows on the roads where several routes of different kinds of public transport are working (See fig. 10). The authorities can make macro analysis of the intensity of passenger’s flows along the arterial roads and main multi-modal intersections which gives ground to a decision-making for optimization of public transport’s route network or its schedules.

Correctly designed data structure of the system provides the connection with the other information systems, such as, for example, GIS of Moscow, Automated system in the dispatch center for managing public transport traffic, Automated system for collecting fairs and Automated system for designing schedules of public transport.

The main effects from application: It is provided exact enough (mistakes within the limits of 4 - 10 %) the constant automated account of quantity of actually transported passengers on city ground transport. The set of the information for carrying out of various analyses is formed: from an estimation of actual volumes of passenger traffic on routes, highways and directions up to the control of actual proceeds over each vehicle (at 100 % to payment of travel by passengers). There is an objective basis for effective planning routing.

**DIRECTIONS OF INTEGRATION OF ITS-RELATED TECHNOLOGIES OF URBAN TRANSPORT SYSTEMS**

Summarizing, it is necessary to note, that creation and development of uniform ITS of city of Moscow is planed to be based on the general organizational-technological platform of navigating systems, control systems of traffic flows, etc. - from accounts of uniform coordinate (position data), time and the navigation support - under the conception of creating unified city analytical center (See fig. 11).

Efficiency of the given systems provides total efficiency of construction city ITS from the point of view of investment appeal of projects.
Under this conception, ITS architecture is primarily about information exchange and control between systems at various levels of abstraction, as depicted in the multi-level model in Figure 12.

![Multi-level Model](image)

The concerned project (the scheme of integration of the automated control systems of transport in Moscow (conception) defined these levels as a way of explaining the uses that should be made of the various models and viewpoints that may comprise an architecture.

<table>
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**CONCLUSIONS**

ITS offers immense scope for integration, and some argue that it is only through integration of ITS components that ITS will achieve its full impact. Key ingredients are thorough planning, good communications and effective coordination of partners and stakeholder interests.

Currently, many ITS deployments are stand-alone applications since it is often more cost-effective in the short run to deploy an individual application without worrying about all the data exchange interfaces, communication links and different hardware platforms required for an integrated system. However, for ITS to take the next steps forward, it will be important both for efficiency and effectiveness reasons to think in terms of system integration. While this integration certainly adds complexity, it is also expected to provide Russian economies of scale in system deployment and improvements in overall system effectiveness, for example by integrating advanced transportation management systems (ATMS) with advanced traveller information systems (ATIS) in Moscow. For the most part, these two groups of services, while conceptually interlinked, have developed independently.

Another aspect of system integration is interoperability - ensuring that ITS components can function together. ITS services can make transport safer and more secure. They can maximise its capability to contain and reduce the impact of disasters, natural and man-made, e.g. by forward planning, cutting emergency service response times, and securing and prioritising disaster evacuation routes.
Current technology trends are enhancing the promises of increased safety and productivity for tomorrow's intelligent highways. The increasing availability of more powerful, yet less expensive software-driven GNSS receivers, integrated with other positioning technologies and wireless communications, will provide the knowledge of traffic flow and status that is the essential element of any intelligent highway system.

The benefits of ITS are plentiful and reach into every sector of the transport realm. It is possible to examine which coordinate (position data), time and the navigation support for ITS-related technology and applications have been the most successful, which have been less successful and what are the underlying factors that determine success or failure.

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ANALYZING THE LEVEL OF HIGH TROPOSPHERC OZONE DURING THE SUMMER 2014 and 2015 IN SKOPJE, R.MACEDONIA

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Abstract:

Ozone is health-hazardous air pollutant and his level in the living environment is very important to be tracked and understood. This specific gas in nowadays occurs as byproduct of certain human activities, especially with car pollution and naturally due to increased temperature. Therefore, it is important to understand the relationship between this variable. The focus of this paper is to model this relationship, with data collected for period of 3 months in 2014 and 2015(summer period). According to the models obtained with machine learning methods, high level concentrations of ozone was found if temperature of the air is higher than 30.15°C and concentrations of NO2 are lower than 16.93 mg/m3(in 2013). Encourage by this model, in this paper we go further and extend our research to include more data (from 2014 and 2015) and different methods to find other influencing factors that contributes to high concentration of ozone.

KEYWORDS: THRESHOLD OZONE, DECISION TREE, ENVIRONMENTAL PARAMETERS, TROPOSPHERE

1. Introduction

We have all heard about the ozone layer, located at an altitude of 25-30 kilometres and a width of 20 kilometres that protects us from harmful UV radiation of the Sun, thus protecting life on Earth. This is called “Good ozone layer”. However, ground-level ozone (Ozone located in the troposphere) or the so-called “Bad ozone layer” occurs as a byproduct of certain human activities across the globe. Ozone is the only pollutant of nature that is not obtained directly from the source of pollution, but as a result of interaction of nitrogen oxides, volatile organic compounds and meteorological conditions.

The growing number of residents, the majority of vehicles, new industrial plants, global warming is one of the reasons for increased amounts of ozone in the troposphere. Unlike most other air pollutants, ozone is not emitted directly into the air from a source. Ozone is formed by the interaction with the sun[6], particularly ultraviolet light, carbon and nitrogen oxides emitted from vehicles, power plants using fossil fuels, refineries and other industries.

While the ozone in the stratosphere, it protects us from UV radiation, but in the troposphere regarding the environment this pollutant causes adverse effects on growth and reproduction of plants, reduces agricultural yields, affects the ecosystems through changes in water movement, the cycle of minerals / nutrients, habitats, causes disintegration of organic materials, affects the destruction of nylon, rubber and other materials, hurts or destroys animal tissue and it is especially hazardous for people who work outdoors or have respiratory problems.

Fig 1: Ground storm chemistry of ground-level ozone [16]

The atmospheric chemistry of ground-level ozone creation is shown on Fig 1. When ground-level ozone reaches high levels, people should be informed to take extra precautions because respiratory tissue might be damaged, as well as gum tissue, causing damaging cells through oxidation, etc. This can affect the performance of athletes, the occurrence of frequent asthma attacks, irritation of the eyes, chest pain, coughing, vomiting, headaches, exacerbated heart disease, bronchitis and emphysema[13].

Despite the evidence of the harmful effects of increased concentration of ground-level ozone on humans and vegetation, there is constant growth of this pollutant in the EU, US and in other parts of the world[4]. The World Health Organisation[14] emphasises the risk from elevated concentrations of ozone on human health and vegetation and gives instructions for setting the limit value of 100μg/m3 eight-hour daily ozone concentration, although the EU regulation is still with limit value of 120μg/m3. It should be noted that there is no 100% safe threshold level and some individuals may be at risk with limit values less than the recommended ones[1,2,3].

Similar research is being done in R. Slovenia for the town Ljubljana [15] but we would like to extend our research for the town Skopje [17] with more measurements data and more pollution parameters.

2. Data and Methodology

To study the effect and the ratio of meteorological and environmental parameters data mining methods were used. For this purpose, a reliable statistical database of meteorological and environmental parameters was created.

We focus our research for one of the Municipalities in Skopje, the Karposh Municipality because according to the information published on their Web, they reported "exceeding 8 hours of ground-level ozone"[10,11,12].

At higher temperatures, there are higher ozone values, such that our goal will be to determine the threshold temperature value at which ground-level ozone exceeds the limit values set by the 2002/3/EC Directive. The value of ground-level ozone according to this directive is set to 120μg / m³ eight-hour maximum that may be overcame no more than 25 times a year. The average value when the public must be immediately informed is overcoming 180μg/m³, while the alert threshold is at 240μg/m³.
With proper ranking of the considered parameters of the primary pollutants that participate in the creation of ozone, it is possible to identify specific emitters of primary pollutants that initiate the creation of ground-level ozone. Yet the most important contribution of this paper is the possibility to alert the population of most affordable meteorological parameter - the temperature, for possible high concentrations of ozone. This information can be very useful for the risk group of people that will know the temperature at which to apply the advice of doctors. The institutions should be informed in alarm situations when there is increase of air pollution in urban areas and the need for reduction and regulation of emissions in order to obtain better air quality.

The database is consisted of parameters such as ozone, carbon monoxide and nitrogen dioxide, taken from the database of the Ministry of Environment and Spatial Planning of the Republic of Macedonia from the measurement station of Karposh in the period from 01.01.2014 to 31.12.2015. The database also contains parameters such as temperature humidity and pressure, taken from the database of Hydrometeorological Office in the Republic of Macedonia. The database is composed of hourly data in the given time period. Later on, the analysis is limited to the summer months (June, July, August and September). All data was previously processed to meet the demands of selected open source software for data search – WEKA[5].

3. Results and Discussion

The initial examination was conducted with LeastMedSq to establish whether ozone data is linear temperature-dependent or not. However, according to the results we believe that the relationship is nonlinear. In order to determine what is the impact of the other attributes to the ozone, we rank attributes according to the attribute appraiser in WEKA, ReliefFAttributeEval. He implements the instance-based RReliefF method [8] to assessing the relevance of attributes. We use 10-fold cross-validation to calculate the relevance of the attributes. Ranking of the yearly database parameters is presented in Table 1.

Table1: - Ranking of the attributes with RReliefF in correlation with their relevance for prediction of the ozone concentration in the period from 01.01.2014 to 31.12.2014.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature</td>
</tr>
<tr>
<td>2</td>
<td>Pressure</td>
</tr>
<tr>
<td>3</td>
<td>Humidity</td>
</tr>
<tr>
<td>4</td>
<td>NO2</td>
</tr>
<tr>
<td>5</td>
<td>CO</td>
</tr>
</tbody>
</table>

According to the model presented in Fig. 4, the humidity, temperature and the NO2 concentrations are the most important factors for ozone concentrations. High levels of ozone concentrations are present when humidity is lower than 53.5% and the Temperature is higher than 30.15° C. On the other hand, low concentrations of ozone are predicted when humidity is higher than 73.5% and NO2 concentrations are higher than 12.81 μg/m3. It is interesting to note that NO2 concentrations can be found to play a role in low and high concentrations without strict definition of its value, meaning that this parameter can play role in increasing or decreasing ozone concentrations in different combination of humidity and temperature scales.

4. CONCLUSION

Ozone is a health-hazardous air pollutant and its level is increased with increasing of the air temperature. In this paper, we have analysed the summer period of 2014 and 2015 in Skopje, R. Macedonia. The M5P decision tree algorithm was used to analyse the data by creating tree hierarchical models, helping us to find threshold values which determine high and low ozone concentrations.

The main objective of this research is determination the most important factors that contribute to low or high ozone concentrations. According to the decision tree model, we found that high temperatures and low air humidity contribute to high levels of ozone, while low temperature and high humidity resulted in low concentrations of ozone. It is interesting to note, since NO2 concentrations have no particular value range in which contributes to low or high concentrations of ozone, we can conclude that it is important pay factor in reactions forming ozone in different combination scale for temperature and humidity. High temperature is definitely correlated to sunny days when UV light from the sun
not only heats the air, but also increases the ozone concentration through chemical reaction between various compounds.

Therefore, in future we plan to extend our models with more data not only in time dimension, but also including other components that play important role in forming ozone concentration.

5. ACKNOWLEDGMENTS

This work was supported (by using their data bases) from the Hydro- meteorological Institute-Skopje and the Ministry of Environment and Spatial Planning of the Republic of Macedonia. It was partially financed by the Faculty of Computer Science and Engineering, Skopje, R. Macedonia

6. REFERENCES


A STUDY ON THERMAL PERFORMANCE OF LED SIGNAL HEADS USING INFRARED THERMOGRAPHY

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Abstract: This article presents results from a study on thermal performance of several LED traffic light heads. Thermal performance of an electronic equipment, especially LED luminaire, is a lifetime determining criteria. In order to simulate real life worst case scenario signal heads are placed in thermal chamber and the internal temperature is set to 60°C. A controller is made to control the LED signal heads with longest time sequences according to statutory requirements. Constant light mode is studied also. Measurements are made with infrared camera and thermocouple for verification. The measured solder point temperatures are used to calculate junction temperatures and estimate dangerous operating conditions.

Keywords: LED THERMAL PERFORMANCE, INFRARED THERMOGRAPHY

1. Introduction

Light emitting diodes (LEDs) are used for manufacturing of indoor outdoor luminaires, backlights, traffic and commercial signs, traffic signal heads, headlamps, smart lighting system etc. They are used mainly because of their efficiency and manufacturability. The old traditional lighting sources have lots of drawbacks. Incandescent lamp outputs only 8% of the consumed power as visible light, 19% is conducted as heat, and 73% is radiated as infrared light [1]. The useful lifetime for general purpose lamps is 1000h. The luminous efficiency is typically around 14 Lumen per Watt or lm/W. It is better with the halogen lamps with luminous efficacy up to 25 lm/W [2], but still most of the energy is lost on heating. Fluorescent and compact fluorescent lamps (CFLs) are with better efficiency – less than 68 lm/W - but they have limitations in the number of cycles. The efficiency of LEDs is being constantly improved – nowadays white LEDs with efficiency above (80…110) lm/W are easily available and some of the main suppliers announce, that in laboratory conditions they achieved 250 lm/W. However as semiconductor devices, LEDs are sensitive to high temperatures. High working temperatures can reduce the efficiency by reducing luminous flux and can shorten the life of a single LED twice or more. Moreover under normal operating conditions, approximately 50% to 80% [1, 3] (depending on the different LEDs) of the input power of a LED is dissipated through the LED package as heat, while the rest of the input power is converted to light. Therefore thermal management in LED luminaires is highly important for performance and reliability.

Until recently long life incandescent lamps (8000h) were used in traffic lights, there were as well low voltage long life halogen lamps, but the main problem is high consumption and regular maintenance. Due to the use of reflectors there exists possibility of phantom effect in signal heads. In order to cope with these problems new standards and regulations have been imposing their phase out, leaving space for LED only traffic lights, that are more efficient, durable, most with high class antiphantom rating and long lasting. During hot sunny days in the summer, the ambient temperature between traffic light housing and LED signal head may reach or slightly exceed 60°C. That is why thermal measurement is at high importance when estimating lifetime and appropriate design. During operation junction temperature of LED chip must be below (80...85)°C in order to meet the specified by manufacturer of LED chips lifetime [1, 3, 4] of over than 500000h. High working temperatures negatively affect the momentary light output and as soon as the temperature decreases the light output increases.

2. Problem Statement

The thermal generation and distribution in LED luminaire depends on all electrical and mechanical components as in any electronic equipment. Electronic components generate heat which is dissipated, by mechanical components. The model used to describe the thermal path of the heat generated by LEDs to ambient is presented on Fig. 1.

![Fig. 1 Thermal resistance model of multiple LED chips on common MCPCB attached to heatsink](image)

\[ T_j = T_{sp} + R_{thjsp} * P_{LED} \]

\[ T_{led} = T_{sp} + R_{thmcpcb} + R_{thmcpcb} + R_{thha} \]

Usually temperature of LED’s solder point is measured and corresponding junction temperature of each LED can be calculated with:

\[ T_j = T_{sp} + R_{thjsp} * P_{LED} \]

where \( P_{LED} \) is the LED chip’s power and \( R_{thjsp} \) is taken from the LED’s data sheet.

As mentioned in introduction part, the power consumed by LED is spent on lighting and heating. The electrical power consumed by LED is a sum of the heat loses \( P_{heat} \) and light output or optical power \( P_{opt} \) [1, 5].

\[ P_{el} = P_{heat} + P_{opt} \]

In thermal management \( P_{heat} \) is used, conservatively it is assumed to be 75% of the LEDs input power [6]. This value varies with different LEDs regarding current density, brightness, etc, but is a good estimate for thermal design. The following equation shows how to calculate the thermal power:

\[ P_{heat} = 0.75 * I_F * U_F \]
In LED modules separate LEDs are soldered to a common board – either MCPCB aluminum base layer covered with ceramic dielectric and copper soldering layer, or traditional FR4 PCB with multiple copper vias under and around LED chips to improve heat conduction between upper and lower copper layers. Among the tested LED heads there were both types of boards.

In order to acquire correct values of temperatures of each LED several techniques may be applied – with thermocouple probes, with infrared thermography or with using the p-n junction of the LEDs as sensors. The last method is pretty time consuming because for each LED or module the specific forward voltage – temperature relation must be obtained experimentally, but provides accurate “in situ” measurements as previously investigated [7]. And for a LED module with known relation, the procedure requires only forward voltage measurements for obtaining junction temperature.

Thermocouple probes are most common method used for measurements, and are recommended by LED manufacturers for precise measurements. [8, 9, 10]. However this method for solder point’s temperature measurements has considerable disadvantages. Practically the temperature can be measured in a few points only. It is impossible to estimate temperature distribution on all LEDs in the light equipment and to verify the correctness of results, obtained by modeling and by thermal management’s calculations. The assumption about $P_{\text{heat}}$ or the LED (equation (4) ) also introduces some degree of inaccuracy.

Thermal (infrared) camera measurements are convenient for quick visual representation of the heat spreading through LED system. However, using an IR camera for absolute temperature measurements can be very complex and may lead to inaccurate results. Knowing the exact emissivity of the material is crucial for accurate results, but often it is not precisely known. One way to overcome this is to take a measurement with a thermocouple and then adjust the emissivity setting on the IR camera to match these results.

3. Materials and methods

In order to simulate the real life operation of traffic signal heads a sequence controller based on MCU is designed. The duration of each signal is programmed according to the statutory requirements for maximum red or green signal which are 81s maximum green with 39s off time and 109s maximum red with 11s off time, where the allowable cycle is 120s.

When performing thermal measurements, the system under examination must be tested at worst real life conditions expected during operation. In our case the maximum ambient temperature for the LED head is measured to be 60°C. This is the temperature inside traffic light housing during sunny summer days. To achieve this, the traffic signal heads are placed inside thermal chamber with precisely controlled and measured temperature. The experimental set up is presented on Fig. 3.

4. Results

Each LED signal head is cyclically switched on and off by the sequence controller, in the chamber and left until thermal equilibrium is reached. For each one, the temperature rise for each cycle, from the time being switched on to the time being switched off is recorded. The results are presented on Fig. 4.
As mentioned, thermal imaging has lots of advantages during measurement, the pictures of the first group of LED signal heads (figures 5 to 8) present information about thermal load, not only for single led chips, but for some exposed driver components. It is visible that the main switching transistor does not exceed 78°C, on its thermal dissipation plate even at constant mode (Fig 6 and Fig 8), which means less than 90°C junction temperature which is inside safe operation limits for this transistor, specified by its manufacturer. Capacitor temperatures also stay below their limits for safe operation.
Table 1: Measured solder point temperatures, and calculated junction temperatures, for the LEDs in the examined traffic signal heads.

<table>
<thead>
<tr>
<th>LED head</th>
<th>Green 1</th>
<th>Green 1</th>
<th>Red 1</th>
<th>Red 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>time on, s</td>
<td>cycle 81</td>
<td>const</td>
<td>cycle 109</td>
<td>const</td>
</tr>
<tr>
<td>$T_{SP}$ °C</td>
<td>72.1</td>
<td>77.1</td>
<td>73.4</td>
<td>76.6</td>
</tr>
<tr>
<td>$T_{J}$ °C</td>
<td>78.85</td>
<td>83.85</td>
<td>77.66</td>
<td>80.86</td>
</tr>
<tr>
<td>LED head</td>
<td>Green 2</td>
<td>Green 2</td>
<td>Red 2</td>
<td>Red 2</td>
</tr>
<tr>
<td>time on, s</td>
<td>cycle 81</td>
<td>const</td>
<td>cycle 109</td>
<td>const</td>
</tr>
<tr>
<td>$T_{SP}$ °C</td>
<td>71.9</td>
<td>73.5</td>
<td>72.1</td>
<td>72.9</td>
</tr>
<tr>
<td>$T_{J}$ °C</td>
<td>83.6</td>
<td>85.2</td>
<td>80.63125</td>
<td>81.43125</td>
</tr>
</tbody>
</table>

It is visible that junction temperatures do not exceed 85°C, which means those modules are expected to live at least 50000h. Only LED Green head 2 at constant operational mode slightly exceeds 85°C, but having in mind that such extreme ambient conditions of temperatures close 60°C inside traffic light housing are only present in hot summer days, the overall lifetime is not expected to be significantly affected.

5. Conclusion

Thermal performance measurements with infrared thermography of 4 traffic signal heads from two manufacturers are performed. The results are good and show, that at worst ambient conditions, during cyclic operation junction temperatures of the LEDs stay below 85°C. Even at constant mode, junction temperatures are close to the safe operation zone ensuring long life service.

References

[1] Thermal Characteristics of LEDs, ledlight.osram-os.com
Abstract: Nowadays hybrid vehicles take increasing share of new road vehicles, but also the electric vehicles have continuous development which is a sign of a serious beginning of new era of their use. The goals of introducing of these vehicles include lowering of the negative impact on the environment and also reducing of their operational costs. Together with the mentioned trends, there are some specifics related to the risks of using this type of vehicles. This paper gives the key elements related to the development of hybrid and electric vehicles with emphasis of the general distinctions in terms of conventional vehicles with internal combustion engines. The paper has focus on risk identification and hazards that can arise from hybrid and electric vehicles, which are specifically related to their technical differences from conventional vehicles with internal combustion engine. Those risks exist when the vehicle is in use, but also even when the vehicle is not in operation. There is also identification of potential risks for the emergency staff when there is accident with these types of vehicles. The paper also addresses the possible harmful events that can happen later or because of improper repairs of the vehicles. Having in mind that the literature sources are quite moderate and in Republic of Macedonia there is none, the conclusion represent an effort to systemize the available knowledge in order to help vehicle users and professionals to mitigate or lower the recognized risks.

Keywords: ELECTRIC VEHICLES, HYBRID VEHICLES, RISKS, SAFETY, PREVENTION.

1. Introduction

The constant increase in environmental pollution, and growing fuel prices contribute to the continuous search for solutions for cleaner transportation. The goal to reduce energy consumption, improve energy efficiency and to protect the environment stimulated people to think of owning hybrid and electric vehicles (EV). Therefore, electrical vehicles are seen as a possible alternative of transportation in terms of low cost of energy, high energy efficiency and low emissions. [4]

Hybrid electric vehicles (HEV) represent the technological bridge that points towards care for the environment, for sustainable and efficient vehicles and limited practicality of pure electric vehicles. The general reason for merging the available technologies are to meet the necessary requirements for performance of the vehicle, meet the desired range of drive with "on-board" energy sources, to ensure optimal energy efficiency and reduce the negative impact on the environment. In HEVs common feature is that these vehicles will supplement the batteries by preserving the kinetic energy generated through regenerative braking via the electric motor / generator which is regulated by the controller. PHEV is relatively simple variation of HEV, however it introduces new implications in the transport and energy infrastructure. [2]

The existence of electric and hybrid vehicles as new technical means with certain technical features, except that it makes them available to assist humanity, as in the case with all other products, they still represent certain danger to their users and the environment. Even if they are stationary certain defects can be dangerous. Their use and participation in traffic affects the potential for the occurrence and consequences of any accidents.

There have been performed hundreds NCAP tests of such vehicles and of all of them there has been a case of an accident of a small fire that occurred as a result of electric shock that burned plastic foam insulation near the radiator which was damaged by the impact. Another danger after an accident that is not present in conventional vehicles is the leakage of acid from the batteries.

This means that fully electric and hybrid electric vehicles introduce new types of dangers. However, the literature points out that the experience with electric vehicles is small, so this area will have to be upgraded once there is more information available. It is known that vehicle manufacturers invest significant resources in the development of safe and reliable electrical systems for the current generation of electric vehicles. Also, it is very important organizations for testing and safety to understand this and be ready for potential hazards [2].

2. Main features of electric and hybrid vehicles

Electric and hybrid vehicles at this stage of development are considered as a significant factor in reducing the harmful effects of emissions from mobile sources and hence the potential of their application especially in urban areas is considered to be high.

A vehicle is considered a hybrid if there is more than one source of energy propulsion of the vehicle, typically an internal combustion engine and electric motor. Electric vehicle though, it is equipped with one or more electric motors. Both vehicles hybrid and electric, have batteries under high voltage, which often are referred to as "rechargeable electric storage systems" (RESS). [2]

In the literature there are several definitions of electric and hybrid vehicles. Most definitions of electric vehicles point out that it is a vehicle powered by power which is provided by the batteries or energy stored in electrochemical device. There are more variations and subclasses of electric or hybrid vehicles and they include: BEVs (battery electric vehicles), HEVs (hybrid electric vehicles), PHEVs ("plug-in" hybrid electric vehicles) and NEVs ("Neighborhood" electric vehicles). In addition, the extended range (range of motion, autonomy) with respect to electric vehicles it allows to compare or to be better than vehicles with internal combustion engine (SAF).

BEV electric vehicle is powered primarily by electricity stored in batteries. EREV electric vehicle is equipped with an electric generator powered by an internal combustion engine that renews the electric propulsion system and extends the operating range of the vehicle. HEV is a vehicle powered by two or more energy sources, one of whom is electric. NEV is a vehicle on four wheels, powered by battery with low speed, with total weight not exceeding 1,400 kg and a top speed of 32 to 40 kilometers per hour. PHEV's vehicle whose batteries can be recharged from an external source in the same way as the electric vehicles.
3. Main characteristics of the hybrid and electric vehicles regarding safety

Electric and hybrid vehicles represent a totally different technology compared to internal combustion engines. This means that new dangers mainly are related to high voltage electrical equipment that is present in the vehicle. Standards already exist for the construction of such vehicles in terms of reducing potential risk towards the passengers and the rescue team who could be exposed to hazards such as corrosive chemicals, toxic gases, fire and electric shock. [2]

Fig. 1 Comparison of results from tests on plug-in / hybrid electric vehicles and conventional vehicle [2]

There are various aspects of electrical safety which should be recognized in electric vehicles:
- Safety of the electrical system;
- Safety in the systems function;
- Safety while charging batteries;
- Maintenance and operation of the vehicle, as well as training [1].

In continuation is a more extensive description for the meaning of the mentioned terms.

3.1 Safety of the electrical system. The safety of the electrical system or the protection against electric shocks encompasses levels of voltage in electric vehicles, protection against direct and indirect contact. Typical levels of voltage for cars and small vans varies from 48V to 120V, for large vans from 96V to 240V and buses from 300V to 600V. For drives with AC using higher voltage, 200V or more can be found even in small vehicles. These voltage levels should be compared to safe voltage levels. Voltages used in electric vehicles are potentially dangerous and should therefore be taken to prevent electric shock in direct or indirect contact. Parts under voltage that are in the electric propulsion system must be protected from direct contact with people in or outside the vehicle through the insulation or inaccessible position. Removal of protection devices must be designed so it will avoid any unintentional direct contact or locking connections. Also the department that houses the batteries must be designed so it will avoid any unintentional direct contact or short circuit.

In terms of regenerative braking there should be some security references. Regenerative braking only operates through a transmission shaft and operating at very low speeds or at a standstill. In some cases the level of deceleration is limited and is not sufficient for immediate braking. The effect of regeneration braking can be reduced when the battery is fully charged. For these reasons primary friction braking system should be able to stop the vehicle under any circumstance.

3.2 Safety regarding the functioning of the systems. The drive system of the electric vehicle must ensure reliable and safe operation of the vehicle. The topology of the drive system in an electric vehicle is fundamentally different from vehicles with internal combustion engine and therefore certain measures should be taken to avoid or prevent unsafe operation. When the electric vehicle stands in place it is completely silent. To prevent inadvertent movement through activation of the drive circuit there must be a warning device. Procedure access must be properly organized in order to avoid possible harm through excessive torque, amperage or excessive acceleration, which means that it should be impossible to activate the controller when the accelerator is pressed. For electric vehicles it is mandatory to have presence of a device (switch) in case of emergencies. Electromagnetic interference coming from outside or from the controller mustn’t affect the functioning of the controller.

Auxiliary power supplies are used for lighting, wipers of the windscreen and other similar burdens. It is powered by the drive battery through the DC/DC converter even though with most vehicles there is auxiliary battery. Regardless of the power supply the work of additional consumers (especially lights) must be assured in all conditions.

In terms of mechanical aspects, since the battery is heavy part of its position it should be determined as to avoid instability of the vehicle and it should be limited to avoid damage in case of accident.

The dangers from chemical aspect depend on the type of battery and on each of the types prescribed way of handling and recycling. Batteries with aqueous electrolyte emit hydrogen due to electrolysis this electrolyte. This especially occurs at the end of charging and should therefore be taken under certain measures to avoid the risk of explosion. During the process of charging the battery, electric vehicle is connected to the main distribution network and should take all precautions to avoid risk of electric shock.

They should consider several cases. "Off-board" battery chargers are commonly used for large vehicles and rapid charging. With these chargers it is essential to connect the vehicle to the ground while the vehicle is full, because it can lead to danger in case of emergency. With "on-board" battery chargers the vehicle must be linked to the ground during charging, except when used Equipment Class II (double insulation). It is recommended to check the correctness of ground through a control device for grounding. When the charger doesn’t have electrical division monitoring is necessary of the drive battery isolation and must be isolated from the vehicle body.

Partial "on-board" chargers are based on inductive power transmission. Because they do not involve electrical contact between the vehicle and the power grid, their electrical safety is very high. The absence of cable also reduces mechanical risks. However, the characteristics of the electromagnetic environment in these chargers are still under consideration.

3.3 Battery safety. The battery is the most critical part for electric vehicles. It presents several potential hazards: electrical, mechanical, chemical and danger of explosion. The electrical aspects include protection against electric shock and short circuit. Therefore, it should be provided for protective devices – fuse of the battery. When using multiple batteries it should provide more locking connections. Also the department that houses the batteries must be designed so it will avoid any unintentional direct contact or short circuit.

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Partial "on-board" chargers are based on inductive power transmission. Because they do not involve electrical contact between the vehicle and the power grid, their electrical safety is very high. The absence of cable also reduces mechanical risks. However, the characteristics of the electromagnetic environment in these chargers are still under consideration.
3.4 Maintenance. In the first line of maintaining is the user. Ordinary consumer is not a trained electrician and must therefore be protected against all risks of direct contact. The second row in the maintenance is the workshops. Employees at workshop (service) must be thoroughly trained in the safe maintenance actions in servicing of electric vehicles. The battery should be disconnected before any kind of intervention. Third row are holding workshops manufacturer and include the main electrical repairs. This should be done only by trained personnel. Besides maintenance of mechanical parts it is necessary to have electrical and routine maintenance for safe operation. These include testing the resistance of insulation and earth leakage functioning controller, battery status as well as its maintenance and cleaning.

The electric car is not similar to petrol, diesel and other kind of vehicles. The electric motor has the characteristics of torque and power that are quite different from the internal combustion engines. Safe and energy efficient electric driving vehicle requires appropriate skills. For electric vehicles there is no room for everyday driving style as it is with petrol vehicles. Especially the charging should be done properly and with the necessary discipline. Therefore buyers of electric vehicles must be provided with the necessary information through the seller.

4. Groups of risks associated with hybrid and electric vehicles

Various risks associated with the new technology of electric vehicles must be carefully weighed. It is necessary at the same time to be aware of new risks, but their levels should not be overvalued because of fear or ignorance.

In circumstances where there is no richer experience, as with conventional vehicles, risk assessments can be based on known differences that electric and hybrid vehicles are introduced in the not as numerous examples of adverse events and associated accidents with them.

As stated above, electric and hybrid vehicles have a number of security issues that are not related to conventional vehicles, and include electric shock, explosion, flood of the electrolyte and fire. There are examples of practice where electric vehicles are burned in an accident or burned in the garages where they were kept. In some cases this happened while the vehicle is being filled. [2]

Regardless of whether the vehicle is in use or idle greatest concern with electric or hybrid drive is the uncertainty associated with the state of the battery after mechanical damage. Sometimes, the connectors may be defective and to lose communication with one or all parts of the battery with unknown amount of energy remaining in the system. In this case handling and removing becomes a significant problem. Issues related to the malfunction of the battery after damage will be evidence of leakage, leaking electrolyte (carbon solvents are flammable), thermal hazards (observed battery temperatures exceeding 1200°C after malfunction) and hazard particles. Therefore prescribed tests that simulate different environmental, mechanical and electrical conditions where the batteries will be tested.

The most widely publicized incident involving a fire happened in 2011 with Chevrolet Volt after it has undergone a crash test in MGA research center. The batteries ignite three weeks later after being subjected to a side impact of 30 km/h as part of the NCAP test. The fire quickly spread to neighboring vehicles. Extensive investigation into the fire showed that a small amount of coolant entered into the housing of the battery at high voltage collision, which caused a short circuit and eventually led to uncontrolled heat state in terms of the temperature.

In 2012 after the Sandy Hurricane at the port in New Jersey sixteen electric vehicle Fisker Karma were burned and destroyed. Presumably flooding caused a short circuit in the battery which led to disruption of the thermal condition. Then the fire spread to finally ignite fifteen other neighboring vehicles.

In 2013 two Tesla model S vehicles caught fire while being driven in USA. First in Washington sparked after the car hit a metal object on road. The second vehicle accident occurred after the vehicle has run over the plug trailer - hook in Tennessee. In both cases remains on the road penetrated through the floor causing damage to the batteries leading to battery failure and thermal instability. After both cases the company Tesla said they will add extra protection to the undercarriage of the vehicle to protect the battery.

In 2014, car thief crashed into another car at high speed where the vehicle broke in two. Battery flew out of the vehicle and caught fire.

For each type of today's common battery systems (such as lead acid, nickel-metal hybrid and lithium-ion) there are recommended methods for handling by the emergency staff, depending on whether the incident was a fire in the collision which damaged the housing of the battery or other hazardous event (ex. flooding). Manufacturer literature often provides specific details on how to deal with specific batteries. However, this information is not always consistent and not always easily accessible for the emergency staff. [3]

Despite the danger that may arise from these vehicles for users themselves SAE (Society of Automotive Engineers) highlighted the risks for those who are the first help assistance in case of accident and towing services. These risks include potential electric shock from damaged systems that are turned off during or immediately after crash. Because of this, the association recommends that manufacturers of electrical vehicles install switches that will stop the energy from the battery case in accident. The location of these

Fig. 2 Chevrolet Volt car that caught fire in the garage [6]

Fig. 3 Tesla S vehicle on fire due to penetration of the batteries and causing a short circuit [6]
hybrid and electric vehicles must be equipped with a warning that
hybrid and electric vehicles moving at low speeds. Therefore,
recognize and interpret his movements, which is not the case with
impossible to detect. Every vehicle should produce enough noise to
Too high sound means impossible to make a difference and too low
can be interpreted only when the sound is at an appropriate level.
vehicle approaching from the rear. However, information exists or
time to change lane or a sign they can relax because there is no
movements. They also use the lack of noise to choose the right time
to cross the street. Cyclists can interpret lack of noise as the right
to make a difference and too low impossible to recognize and interpret his movements, which is not the case with
hybrid and electric vehicles moving at low speeds. Therefore,
hybrid and electric vehicles must be equipped with a warning that
will allow pedestrians to reveal their presence and direction of
It is expected in the next 20 years the number of small light
electric vehicles (SEVs) to significantly increase and become future
solution for urban mobility because of their dimensions. These
vehicles will have short front and rear overhang and will be
allocated to less than 5 passengers. Clashes between SEVs and
vulnerable road users and other heavier vehicles will differ from
those of current traditional vehicles. Protection of vulnerable road
users, compatibility with heavier vehicles and new active safety
systems must be taken into account to ensure adequate security of
SEVs in the future regulations [5].

5. Conclusion
It is clear that the use of electric and hybrid vehicles in the
future will be one of the main landmarks in the development of
transport. Their use will be encouraged in order to protect the
environment and depletion of fossil fuels.

By applying this completely different technology people must
be ready for new risks that come with it. It applies to all segments
of using hybrid and electric vehicles: the habits and rules of
participation in traffic, storage, maintenance, charging, and
procedure in case of an accident.

The introduction of electric vehicles will require compliance
with security rules that are inherent for the electrical drive. Electric
vehicles will become safe and reliable way of transport which will
improve traffic and the impact on the environment in the future.

People who are professionally working in this area must be
trained on how to react in case of an accident. Although the use of
this type of vehicles will enter later in our country we should be
prepared to support the vehicles that will be passing through the
country. They should be aware of and trained for challenges arising
from an accident involving an electric or hybrid vehicle.

Performed crash tests are made with particular attention to the
unique dangers associated with high voltage batteries. However, the
market introduces new types of electrical drives and therefore the
laboratories security practice will need to develop. Current
procedures for safety of electric or hybrid vehicles are a good
starting point for developing new ones.

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Investigated in this work were four samples of the motor oil Genuine 5w-30 dexos 2, namely: the fresh one and three ones taken after car miles 180, 430 and 712 km. When measuring the kinetics of refraction indexes for the studied samples of used oil, the authors observed a characteristic “shoulder” caused by sedimentation of oxidation and wear particles on the surface of SPR device sensitive element, while in case of fresh oil there took place only the temperature drift of the refraction index. It has been experimentally shown that using the SPR characteristic “shoulder” can be offered to control quality of motor oils as well as the degree of wear inherent to interacting parts of machinery.

The aim of this work is to study possibilities for simultaneous control both the state of motor oil and wear degree of car engine parts at early stages of its operation as well as determination of oxidation and wear products concentration with high sensitivity and productivity.

2. Prerequisites and means for solving the problem

2.1. The model of effective medium that describes availability of oxidation and part wear products in motor oil

The motor oil with oxidation and wear products can be represented by the model of suspension containing a disperse filler. Knowing the values of refraction indexes for pure and used oils, one can determine the impurity percentage. Let us consider the pure motor oil as a matrix, and oxidation and wear products as filler. The most spread approaches to describe this system are the Wiener limits as well as Maxwell-Garnett and Bruggeman models. In these approaches, they introduce the conception of “effective medium” with some efficient refraction index, the value of which lies between those of matrix and filler. Wiener’s limits [11] describe boundary values of the efficient refraction index in the model of layered structure (Fig. 1a) [12]. In this case, the medium efficient refraction index depends on direction of the field electric component. If it is oriented along the normal to composite layers, then the composite dielectric permittivity is defined by Exp. (1), but if it is parallel to composite layers – by Exp. (2). The refraction indexes for these two cases of field component directions are the Wiener limits, and they can be determined as roots of respective dielectric permittivities.

\[
\varepsilon = f_1\varepsilon_1 + f_2\varepsilon_2, \quad (1)
\]
where, \( f_1 \) and \( f_2 \) are volume fractions of suspension components; 
\( \varepsilon \) is the relative dielectric permittivity of suspension; 
\( \varepsilon_1 \) and \( \varepsilon_2 \) are relative dielectric permittivities of suspension components.

Since oxidation and wear products are located chaotically in motor oil, this approach can be applied only for determination of the possible range for suspension efficient refraction index values. The approaches by Maxwell-Garnett and Bruggeman seem to be more efficient, since they were developed especially for media with chaotically located of filler particles in the matrix. The main condition of applicability of the Maxwell-Garnett approach [13] is a small size \( a \) of nanoparticles in comparison with distances between them \( b \), and, as a consequence, their low volume concentration \( f \) in the total substance mass (Fig. 1b).

Within the framework of Maxwell-Garnett model, the medium has a dielectric permittivity related with permittivities of components by Exp. (3). The Bruggeman model [14] is applied when volume fractions of components \( f_1 \) and \( f_2 \) are in relation from \( 1/3 \) up to \( 2/3 \), which corresponds to the case of high concentrations:

\[
\frac{1}{\varepsilon} = \frac{f_1}{\varepsilon_1} + \frac{f_2}{\varepsilon_2},
\]

(2)

\[
\varepsilon - \varepsilon_2 \varepsilon + 2\varepsilon_2 = f \varepsilon_1 - \varepsilon_2 \varepsilon_1 + 2\varepsilon_2
\]

(3)

where, \( f \) is the volume fraction of nanoparticles in suspension; 
\( \varepsilon \) – relative dielectric permittivity of suspension; 
\( \varepsilon_1 \) and \( \varepsilon_2 \) are relative dielectric permittivities of nanoparticle substance and matrix, respectively.

As initial data for modeling, one can use optical constants of synthetic motor oil and the main component of wear products – iron. Since in accord with the set task it was necessary to control quality of oil at early stages of operation, when the concentration of oxidation and wear products is low, we used the Maxwell-Garnett approach for determining the wear products concentration.

2.2. Structural schematic of the experimental setup and method of investigations

The experimental setup (Fig. 2) consisted of the thermostat (Fig. 3b), where the SPR refractometer “Plasmon-71” (developed in Lashkaryov Institute of Semiconductor Physics, NAS of Ukraine) (Fig. 3a) and container with motor oil samples were placed.

Fig.2. Schematic experimental setup: 1 – thermostat; 2 – container with a motor oil sample; 3 – SPR refractometer; 4 – measuring cell of the refractometer; 5 – oil-gun pump; 6 – connecting pipes for pumping oil in and out.

Fig.3. Appearance of the SPR refractometer (a) and thermostat (b) with refractometer and motor oil container.
Operation surface of the refractometer sensitive element is made of the gold film with the thickness 50 ± 2 nm deposited on a glass substrate. To excite surface plasmons in the gold film, we used p-polarized light from a semiconductor injection laser diode with the wavelength 850 nm. Necessary conditions for excitation of surface plasmons were provided by changing the angle of laser light incidence onto the sensitive element surface. The angular dependence of reflected light intensity \( R(\theta) \) serves as a main device original characteristic. To determine the refraction index of motor oil samples and its changes in time, specified in this device are two operation modes: Multiple and Slope. Changes in the analyte refraction index cause a shift of the \( R(\theta) \) minimum.

In the Multiple mode that was used in experiments, we performed periodical measurements of \( R(\theta) \) characteristics to determine the angular shifts of their minima \( \Delta \theta \), which is necessary for calculations of the refraction index inherent to the studied substance. The minimum of the measured characteristics was approximated with the polynomial of the 2-nd degree to reduce the measurement errors caused by a finite step of angular scanning the reflection characteristic. Then, we determined the angular position of the minimum for the approximating polynomial \( \theta_{\text{min}} \) and calculated the respective refraction index that was considered as the result of these measurements.

We carried out the measurements of the refraction indexes for four samples of synthetic motor oil Genuine 5w-30 dexos 2, namely: before using it in the car engine (fresh) as well as after its operation for the mileages 180, 430 and 712 km (used). Being based on assumption that the wear products will be deposited onto the surface of refractometer sensitive element under the gravity force action, we performed measurements of kinetics (changes in time) of the refraction index for the studied samples by using the SPR refractometer “Plasmon-71”. In addition, we measured the same samples with the optical refractometer RL3.

The latter measurements were performed to demonstrate advantages of the SPR method in solving these tasks. The instrumental errors \( \Delta \theta \) in measurements of the refraction index by using the devices RL3 and “Plasmon-71” are as follows: ±0.0002 and ±0.00001, respectively. For each sample of motor oil, the SPR refractometer was used to perform a series of 10 sequential measurements, which enabled to determine the limits of methodical errors when measuring the refraction index. These limits are ±0.00002. Using the values of optical constants for iron \( \varepsilon = 2.7180 \), which is necessary for dielectric permittivity \( \varepsilon \) of the studied samples as well as results of calculations of the refraction index ±0.00002.

### 3. Results and discussion

The refraction index values for the samples of motor oil Genuine 5w-30 dexos 2 were experimentally determined with the devices “Plasmon-71” and RL3 (Table 1). The difference between values of refraction indexes measured using the above devices is caused both by its dispersion and by the fact that optical refractometer gives the value of bulk refraction index, while the SPR refractometer gives the surface one.

Adduced in Table 1 are also the calculated values of the relative dielectric permittivity \( \varepsilon \) for the studied samples as well as results of calculations for the bulk concentration \( f \) of nanoparticles related to wear products in accord with the Maxwell-Garnett model. The errors of \( \varepsilon \) and \( f \) calculations are ±0.00005 and ±0.0005, respectively.

The dependence of motor oil refraction index on car mileage (Fig. 4) has a linear character and can be approximated by a linear function with the high matching factor \( R^2 = 0.9973 \), which enables, using this function, to calculate the minimum car mileage necessary to control quality of motor oil and to determine the bulk concentration of wear products. Shown in the fifth line of Table 1 are this minimum car mileage and the respective value of the bulk concentration of wear products for oxidation and wear products in motor oil determined using the SPR method with the errors in measurements of the refraction index ±0.00002.

![Fig. 4. Dependence of the refraction index for the samples of synthetic motor oil Genuine 5w-30 dexos 2 on duration of its operation in the car engine and the result of linear approximation of this dependence with the function y(x)=A+B·x, where A = 1,456, B = 1.382·10^-4, matching factor R^2 = 0.9973.](image)

The difference between refraction index values inherent to the samples of used motor oil determined with the optical refractometer corresponds to errors of measurements by using this device, which provides its resolution by wear products concentration \( f_{\text{min}} = 0.17 \) vol.%. While the resolution of the SPR refractometer equals to \( f_{\text{min}} = 0.0107 \) vol.%, which improves by more than one order (16 times) the detection limit, i.e., considerably enhances sensitivity of measuring the wear products concentration in motor oil.

### 4. Conclusions

Application of the SPR method improves the detection limit and enhances sensitivity by more than one order from \( f_{\text{min}} = 0.17 \) vol.% down to \( f_{\text{min}} = 0.0107 \) vol.%, when measuring the concentration of wear products in motor oil, as compared with the known refractometric method. It enables to determine availability of these products at early stages of car exploitation.

### 5. Literature


