Результати обчислення через реєстр зсуву мікропроцесор подає на цифровий індикатор. При цьому може виводитися значення ємності первинного перетворювача, зміна його ємності, відносне або абсолютне значення вологості середовища. Для спрощення схеми індикації і зменшення кількості виводів мікропроцесора використано динамічний порозрядний метод індикації.

Описана структура вимірювача вологості дозволяє усунути похибки від впливу струму СЗС і зразкової напруги U_0. Точність вимірювань при цьому визначається точністю конденсатора зразкової ємності і первинного перетворювача.

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SMART STRENGTH SENSOR FOR WHEEL LOAD MEASURING OF RAILWAY CARRIAGES

Описано спеціалізований сенсор сили для вимірювання навантаження на колеса в залізничних вагонах. Сенсор вбудовують як елемент залізниці як частину стандартної P49 рельси і монтують на рельсовий болт для заземлення. Два вимірювальні мости для вимірювання поперечної сили монтують на рельсі на заданих відстанях від кінців рельси. Практично запропонований інтелектуальний сенсор використовує локальну зону дії сили. Сенсор вимірює прикладену силу і оцінює реальну позицію дії сили. Пропонований інтелектуальний сенсор тестують разом з електронною частиною. Запропоновано технологію для вирівнювання чутливості вимірювальних мостів та калібрування сенсора. Сенсор застосовують для вимірювання статичного та динамічного навантаження на колесо вагона.

The subject of the paper is a specialized strength sensor for measuring the wheel load of railway carriages. The sensor is built on an element of the railroad, as a part of standard P49 type rail mounted on standard rail clamps. Two strain gauges measuring bridges for the tangential forces are mounted on the rail at a certain distance from the both ends. Physically the proposed smart sensor uses the zone where the local effect of the force applied by the force on the sensor spreads. The sensor measures the applied force and estimates the real position of the force. The offered smart sensor is tested together the proposed electronic measuring part. Appropriate technology for equalizing the sensibility of the two measuring strain gauges bridges and for calibration of the sensor is proposed. The smart sensor has been applied in devices for static and dynamic wheel load determining of railway carriages.

1. Introduction

The differences in the static load on the railway vehicle wheels cause substantial negative changes in the process of their interaction with rails. These changes influence on the traffic safety and on the values of the basic reliability characteristics of the running part of locomotives and carriages as well as of the track.

As a result of the locomotive's spring system parameters changed in the process of exploitation, differences in the static load of wheels deviating from the minimal ones could occur as well [1]. The differences could be reduced near to their minimal values by corrections in the spring system. To do that, it is necessary to preliminarily establish the particular load on each wheel in the vehicle static position. With freight cars, the load of their wheels mostly depends on the load disposition. For this biggest group of railway units the problem of the differences of the load on different wheels is particularly significant in connection with the traffic safety and reliability. The quite serious problems can be solved by a system of measurements of the vehicle wheels load in condition of movement.

2. Strength Sensor Construction

A wide range of world-renowned companies offer strength sensors with approved structures [2, 3]. Those classical structures cannot directly be employed for the purposes of wheel load measuring in railway transport. In [4] is presented a smart strength sensor for load measuring of railway carriage wheels (fig.1).

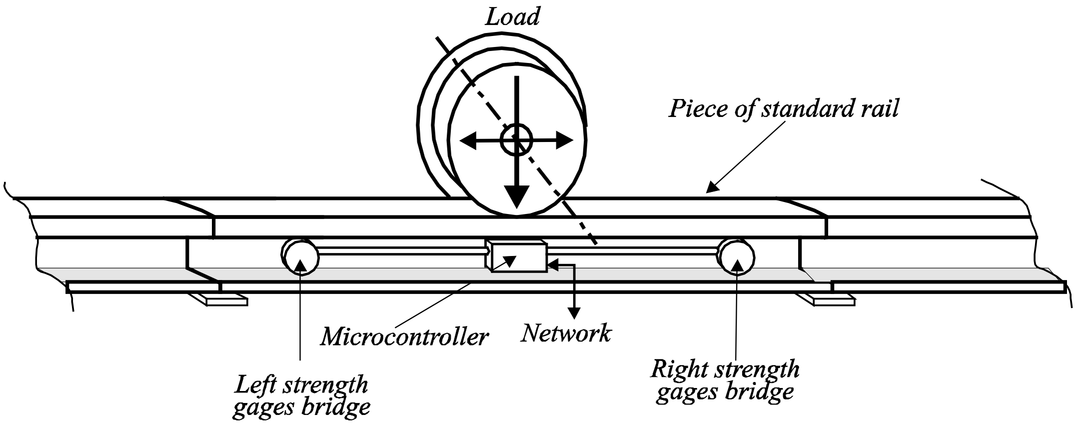

Fig. 1. Construction of the smart strength sensor

The wheel load measuring is done on a special stand that, according to modern concepts, is with immovable sensors of wheel load. A variant of such a stand is the strength-receiving rail being the wheel load sensor itself [5]. That means, the strength sensor is an element of rail-road (part of rail), mounted on standard rail clamps at both ends.

From mechanical point of view (see fig.2) the strength sensor is built on a peace of standard rail type P49 with length of 1140 *mm*. Strain gauges are mounted in the niche area of the peace of rail at its end zones on the two journal sides milled symmetrically to the rail axle beforehand. Electrically they are connected in a two full bridge circuit. The scheme of the strength gauges connection provides the signal received by bridges to be proportional to the tangential force at the section where the bridge is located. The distance between the bridges is 700 *mm*. To increase the transfer factor, at the places of strain gauges the rail journal thickness is symmetrically decreased. The bridges are built of XK11K 3/350 type strain gauges and are applied according to the complete mounting technology recommended by Hottinger Baldwin Messtechnik Co (HBM).

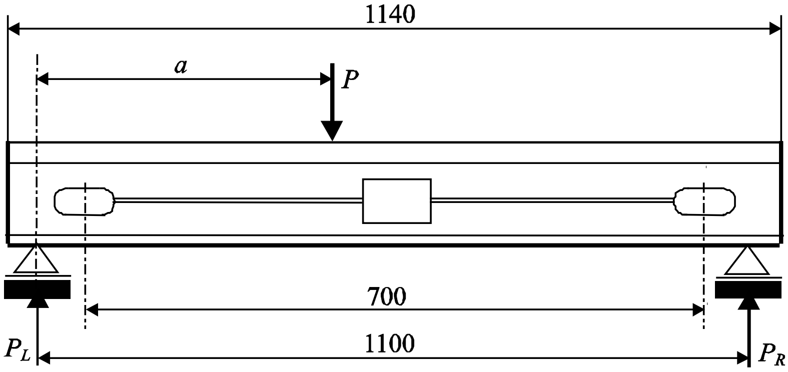

Fig. 2. Scheme of strength sensor load

The smart strength sensor includes an embedded microprocessor system that enhances the signals from the strain gauge bridges, transforms them into digital code and does a digital filtration of the signal. For that purpose AD7730 integral circuit produced by Analog Device Co. has been used. Both strain gage bridges are connected with two separate channels of AD7730 integral circuit. That allows reading individually the signals coming from the two bridges. The sensors are included in a local network built with a data bus topology.

3. Strength Sensor Testing

The main prerequisite for strength sensor application is to determine the sensor zone which is remote enough from the places where the internal forces in the rail are measured. That helps to avoid the local effect of the force applied (the zone where the principle of Sen Venan is applied), i.e. to determine the zone where the wheel can be positioned and its load measured [6].

The zone where the local effect of the force applied onto the sensor spreads is an object of study in a theoretical paper that with the help of analytical and numerical methods in the theory of elasticity (generalized methods of finite integral transformations and the methods of finite elements) has established its value of 0.14 *m* for a certain sensor. From the practical point of view one of the most interesting results of the study mentioned above is that the zone of force local effect gets larger with the decrease of the rail journal thickness at the places of strain gauges mounting.

To obtain experimentally the data necessary for the study, a test set presented in fig.3 has been used. It consists of a metal frame inside which the sensor to be tested is put. A hydraulic jack is used to load it. The force of the jack is measured by C15BC4 standard sensor of HBM. The standard sensor is for the nominal force value of 200 *kN* with a maximal permissible error of 0.05 %. It is connected into the local network together with a personal computer and the tested strength sensor (fig.3).The method proposed reflects the main results of the study carried out to determine the zone where the local effect of the force applied onto the rail by the wheel spreads.

The realized values of the force applied are within the range of 50 ÷ 120 *kN* with a step of 10 *kN*. Ten measurements are done for each force value. With the frame moving, loads with a step of 0,05 *m* are realized along the rail length between the places where the strain gauges are mounted.

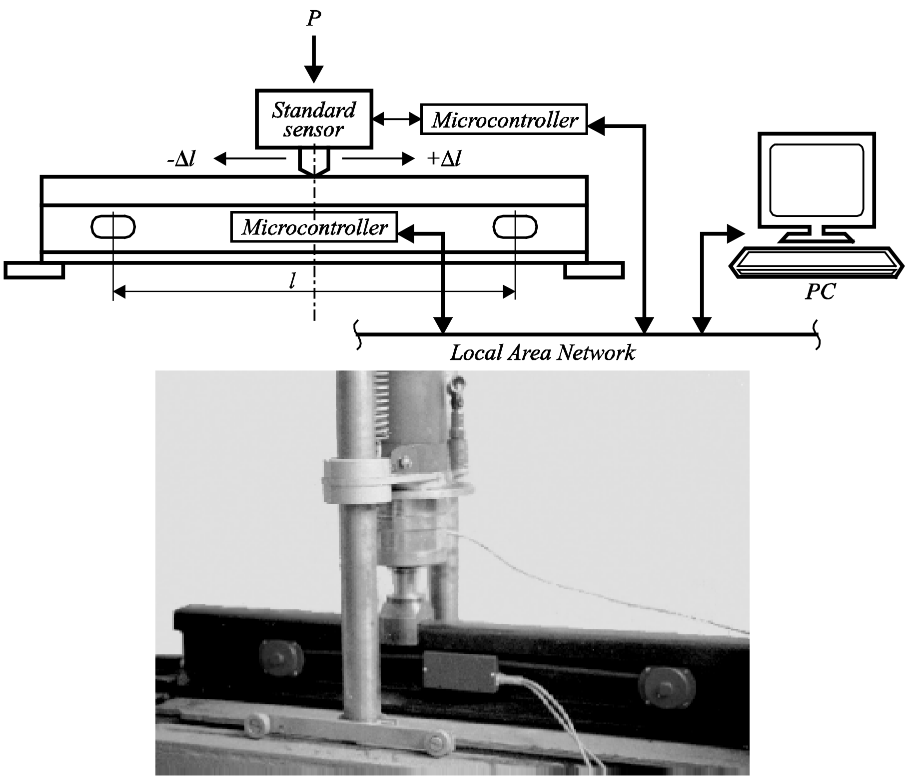

Fig. 3. Experimental strength sensor test stand

The received from the two force-measuring bridges of the sensor tested signals N_L and N_R are in a function of the value and the point of force application P (fig.2). They are processed in the following way:

– the reactions P_R and P_L in the supports of the force sensor are determined as a function of the value and the point of force application P;

– the relations of the signals by the bridges and the relevant reactions are computed N_L/P_L and N_R/P_R;

– the obtained values of relations N_L/P_L and N_R/P_R are regarded to those obtained for the case when force P is applied to the middle of the sensor N_{L0}/P_{L0}, N_{R0}/P_{R0}, the obtained numbers being marked with k_L and k_R

$$k_L = \frac{N_L}{P_L} \bigg/ \frac{N_{L0}}{P_{L0}} \quad \text{and} \quad k_R = \frac{N_R}{P_R} \bigg/ \frac{N_{R0}}{P_{R0}}\,; \tag{1}$$

– for equal distances of the bridges to the point of force P application the values of coefficients k_L and k_R are averaged as the coefficient k_{av}

$$k_{av} = \frac{\left(k_L + k_R\right)}{2}\,; \tag{2}$$

– values N_L/P_L and N_R/P_R are averaged in the zone out of the local effect one, as coefficients m_L and m_R

$$m_L = \frac{1}{n}\sum \frac{N_L}{P_L} \quad \text{and} \quad m_R = \frac{1}{n}\sum \frac{N_R}{P_R}\,, \tag{3}$$

where n is the number of averaged relations of N_L/P_L and N_R/P_R;

– the ratio q of m_L and m_R is determined, that shows what corrections in the sensitivity of the both sensor measuring channels have to be made in order to be with equal sensitivity and the sum of their signals be proportional to force P:

$$q = m_L / m_R \tag{4}$$

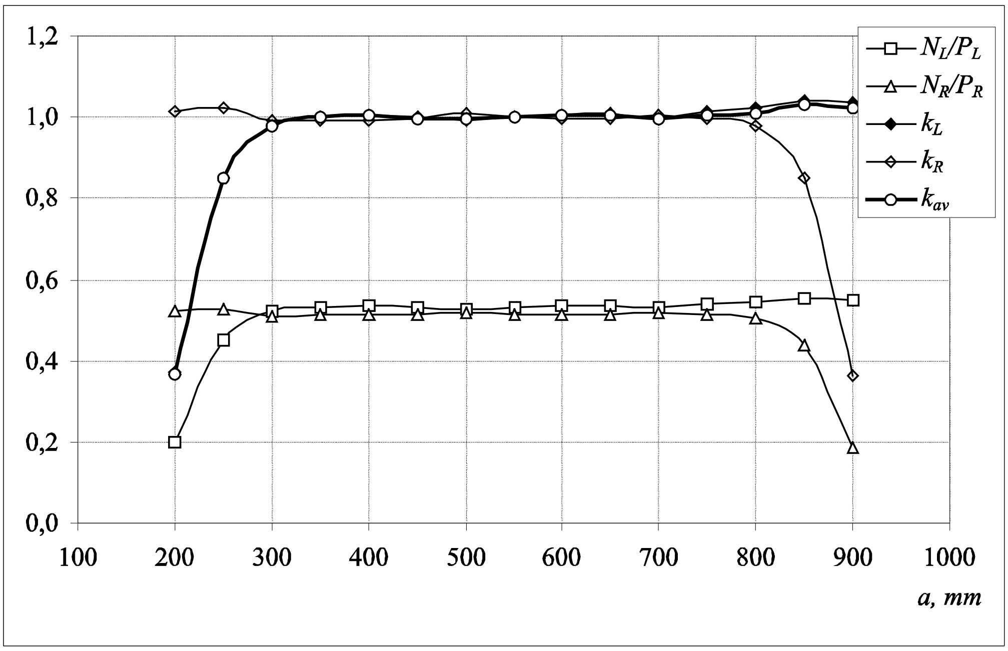

Fig. 4. Signals from strain-measuring bridges depending on the point of force sensor load

4. Locomotive spring system adjustment ideology

The wheel static load measuring is done with immovable sensors being part of railway. That allows the load of all the railway vehicle wheels to be measured at one and the same time. The technology of locomotive spring system adjustment consists of a specific measurement channel and a computer based data acquisition system as shown in fig.5. The measurement channel is a typical railway channel with force measurement devices placed under each locomotive wheel. The number of measurement devices is 12 (for a 6-axles locomotive). They are laid on a horizontal surface with diversions of ± 0.3 mm.

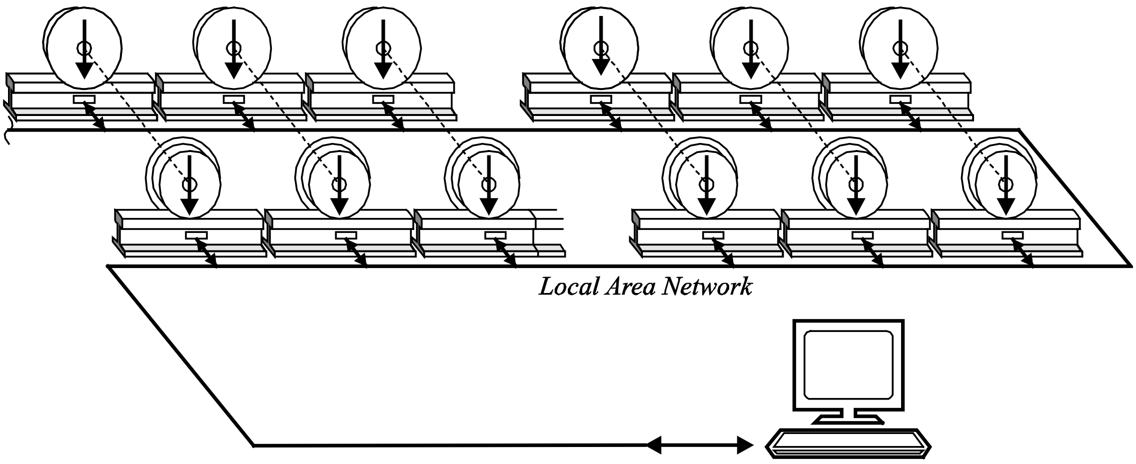

Fig. 5. Structure scheme of the locomotive spring system adjustment

The methods developed give a possibility to achieve the condition of the best spring system regulation by corrections in the dimensioning spring distances and selecting springs of certain force features. Fig. 6 is an illustration of the methods of regulating a six-axle locomotive.

The data of the loads of individual wheels (lines 4 and 5), the absolute (lines 3 and 6) and relative (lines 2 and 7 in percentage) deviations from the average loads of wheel, wheel axles and bogies compared with the accepted tolerance are displayed. The percentage deviations for the condition of the best regulation (lines 1 and 8) have been worked out as well as the calculated values of the corrections to achieve that condition.

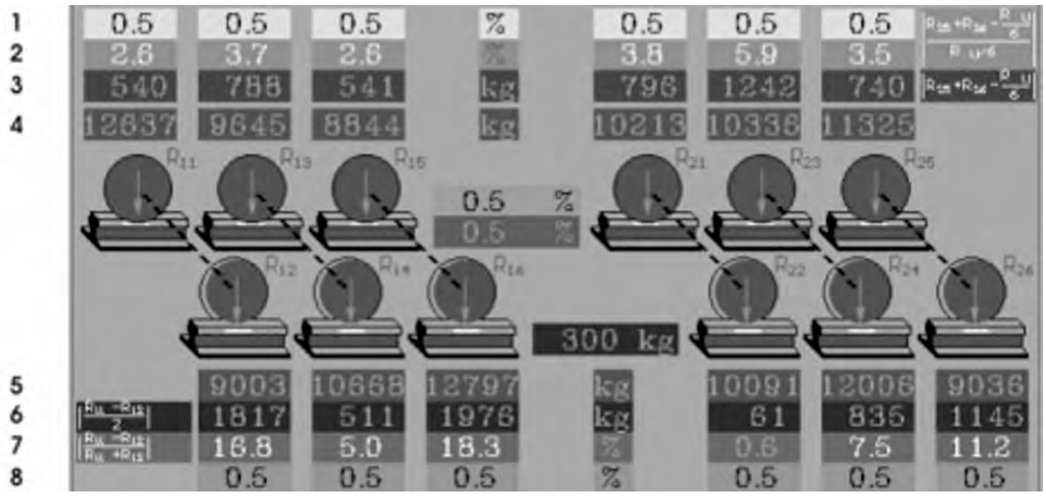

Fig. 6. Displayed information by technology of the locomotive spring system adjustment

5. Measuring Load on Wheels of Running Vehicle

The system of measuring the load on the wheels of running railway vehicles is implemented in a track section in the region of a locomotive shed or station. The track section with a length of not more than 50 meters is characterized with:

– small differences in the levels of the two rails;

– small changes in the railroad elasticity.

It is appropriate to use a section with a dense sleeper grid. A fundament with a length of 2 *m* is built in the middle. Two force sensors are mounted on that fundament with the help of rib bases. Each sensor measures the load on the wheels of one wheel axle (fig.7).

Modified strength sensors with a length of 1360 *mm* have been used. Each modified sensor contains two independent analog-to-digital converters for each strain gauge in order to increase the speed of passing vehicle. On the basis of the theoretical analysis and the experimental test under lab conditions it has been established that the band where the output signal does not depend on the wheel position on the rail is approximately 400 *mm*.

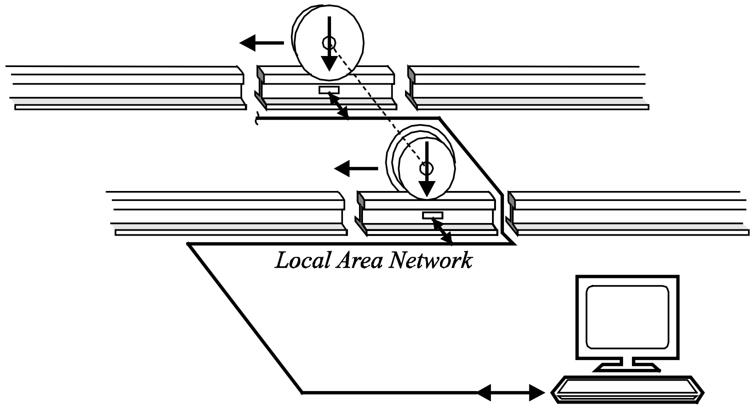

Fig. 7. Equipment for dynamic wheel load measuring of railway carriages

Fig.8 shows the record of measuring the load on a certain wheel on a sensor in the direction of "going in" and "going out". There are present the signals of each of the strain gauges separately and the load summed and registered by the censor. The load on the wheel is determined as an average value of the load summed in the field of the censor position insensitivity.

A specific algorithm for processing the collected data is created. It aims to localize the zone of insensitivity. The algorithm is one-directional, i.e. it processes the signals in the sequence as they arrive.

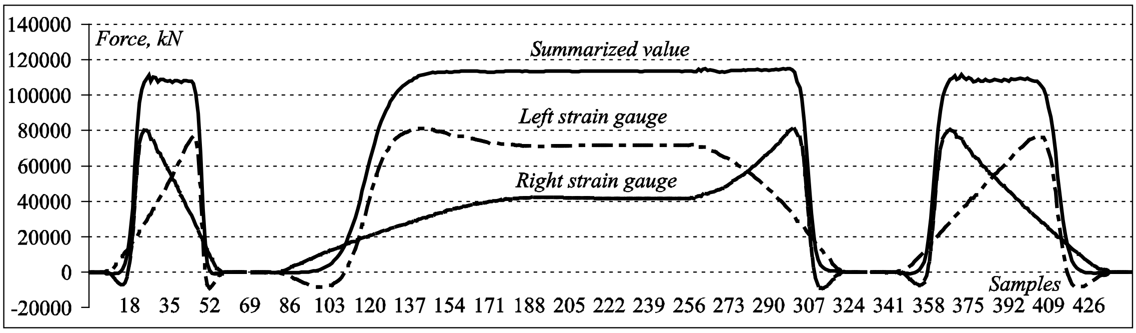

Fig. 8. Experimental results for tree sequential passing of the locomotive wheel

6. Conclusion

The stand equipped with the sensor mentioned has considerable advantages with respect to indices of economic, technological and operational character compared with other possible solutions. Its metrological indices can be high in principle and can satisfy the needs with measuring the wheel load on the base of the expected differences in their load.

There are 8 stands built for the needs of the Bulgarian railways where the measurement devices are connected to the central computer by networking. From a technical point of view, the advantages offered by this technology are the low price, good metrological qualities and high reliability of the system. The continuous improvement of the smart measurement devices has a substantial influence on all repairing and operational locomotive enterprises. That is the reason for the perspectives of building such stands or modernizing the existing ones.

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DYNAMIC TEMPERATURE STATES IN THICK – FILM MICROELECTRONICS ELEMENTS

Описано теоретичний аналіз (порівняний з екмпериментальними дослідженнями) динамічних температурних станів багатошарових мікросхем (виготовлених за технологіями низько- і високотемпературної кераміки). Температура має важливе значення в безвідмовній роботі електронних пристроїв (для прикладу, в газових сенсорах, виготовлених за товстоплівковою технологією, температура визначає основні параметри, такі як чутливість і селективність) і значно підвищує ризик появи дефектів у структурах. Наведено базові моделі та процедуру розв'язання системи рівнянь. Розв'язок для типової товстоплівкової структури порівнювали з експериментальними даними. Розглянуто багато факторів, які впливають на точність отриманих результатів.

The theoretical analysis (compared with experimental investigations) of dynamic temperature states in layer microcircuits (made in LTCC or HTC technology) has been described in the paper. Temperature plays a very important role in proper operation of microelectronic devices (for example in gas sensors – made in thick-film technology – it determines the basic parameters like sensitivity and selectivity) and significantly increases the risk of various defects. The basic models and solution procedures of analytical equations system have been presented. The solution for the typical thick-film structure (active layer placed on alumina substrate) has been compared with the experimental results. The many factors which have influence on accuracy of obtained results have been taken into consideration and discussed. The results of analysis can be used in researches with reliability and tolerance aspect of microsystems (intensity of degradation processes) as well as in determination of thermal properties of the designed systems.

1. Introduction

The intensive development of modern electronics, especially the significant extension of miniaturization is causing the high values of thermal power density generated in particular elements of microcircuit. Moreover, the bigger numbers of microcircuits operate in pulse regime. The emitted heat in