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Alternator diagnostics by means of an oscilloscope and infrared radiation – comparison of methods

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Summary. The article presents an innovative method for testing of the technical condition of an alternator by means of IR camera. Infrared radiation method has been compared with conventional methods, their advantages and disadvantages have been presented herein. ThermaCAM E45 camera manufactured by FLIR has been used for thermovision tests. The tests have been processed by means of FLIR QuickReport software. Furthermore, the article describes the methods of thermovision tests accuracy improvement in order to enable a quick and reliable diagnosis.
Key words: alternative current generator, alternator, diagnostics, thermovision camera, electric power supply circuit.

INTRODUCTION

Alternator is defined as an alternative current generator with electromagnetic or magneto-electric excitation (with permanent magnets) [4]. Its purpose is to supply electrical energy to the battery of motor vehicle and its electric system in the course of combustion engine operation. The power generated by alternator is sufficiently high already at low speeds. It is particularly important in case of motor vehicle operations in idling mode corresponding to about 40% of total operation time in urban traffic [2]. Moreover, the dimensions of alternative current generator are small, its speed range is wide and power-to-mass ratio is high. Currently, the research projects in the scope of design and operational parameters of contemporary alternators are focused on: the reduction of their dimensions and mass, optimization of excitation and cooling circuit and noise reduction [14]. There are many detailed descriptions of design solutions of alternators contained in literature [1, 2, 3]. However, the research methods are significantly facilitated because their operating principle is similar. The modern diagnostic methods most often make it necessary to remove the device from the motor vehicle extending the time required to localize a damage and constituting potential reason of mechanical damages.

ALTERNATOR DAMAGES

The maintenance free operation of alternators application is an argument supporting their application. The scope of periodical maintenance encompasses only the following checks: fastening, cleanness and quality of the conductors and V-belt tension. The alternators damages are divided into mechanical and electrical damages. The first group encompasses the following types of damages: excessively worn brushes, bearings clearances, abrasion of slip rings etc. and are found on the basis of organoleptic tests or as a result of partial disassembly of generator elements. However, further operation of alternator is impossible in case of electric damages. A preliminary evaluation is possible without the necessity to dismantle the unit from the car, but its dismantling is required in order to find a defective element.

In case of an inefficiency, its symptoms can be detected on the basis of indications of dashboard control light (Tab. 1). It is the first diagnostic information indicating the

Table 1. Most frequently occurring symptoms of alternator damages and their reasons

Item	Symptoms	Possible reasons
1.	Control light does not light after the ignition is turned on, with engine not operating	– damaged light – damaged ignition switch – blown fuse – discharged battery – short – circuit of positive diodes

Item	Symptoms	Possible reasons
2.	Low control light after the ignition is turned on, with engine not operating	– discontinuity in rotor winding – worn brushes
3.	Control light does not go off even when ignition switch is turned off	– short – circuit of positive diodes
4.	Control light flashing	– weak tension of V-belt – dirty brushes
5.	Control light does not go off while the engine speed is increased	– damaged regulator – discontinuity or short – circuit in rotor winding of excitation diodes – short – circuit of negative diodes
6.	Low control light with engine operating	– damaged regulator – short – circuit in stator winding – discontinuity in bridge diode – high resistance on contacts – loose conductors

alternator inefficiency. However, no inefficiency is indicated in case of some types of damages, despite the lack of battery charging, e.g. a discontinuity or short – circuit in the regulator circuit of inter-phase short – circuit in stator windings.

CONVENTIONAL TESTS

A quick and reliable diagnosis for damaged machinery is the assumption of primary importance for the creation of new diagnostic procedures for individual equipment elements. As a result of developing technical possibilities, the new methods associated with diagnostic tests quality are created by research centres [9, 10, 11, 17, 20, 21], which directly contributes to repair costs of the operated equipment.

The following checks should be completed in order to enable precise diagnosis for an alternator [19]:
– current efficiency,
– excitation current intensity,
– rectifying diodes,
– regulated voltage,
– alternator leakage current.

Universal meters or oscilloscopes are frequently used in such type of tests. Particular care should be taken in order to prevent any damage of regulator and rectifying diodes as a result of unintended short – circuit or reversal of polarity terminals of the conductors in course of test or when dismantling the device from motor vehicle. The algorithm to be followed in the course of such checks is illustrated in Figure No1.

The rectifying system [15, 16] is the most sensitive part of alternators. The rectifying diodes can be subject to damages occurring mainly when exceeding the rated current values (in conducting direction) and reverse voltage (in reversed direction). A discontinuity or short – circuit, even in one diode, contributes to faster wearing of efficient diodes of the bridge and consequently leads to inefficiency of the whole rectifying system.

The possible reasons of damages in the rectifying system as well as in the electrical systems of the generator (windings) are: reversal of battery polarity or battery disconnection in course of alternator operation, disconnection of B+ (positive) terminal of alternator from the motor vehicle electric system in course of its operation, high environment temperature in course of alternator operation under high load. Furthermore, the mechanical damages are possible in course of repair.

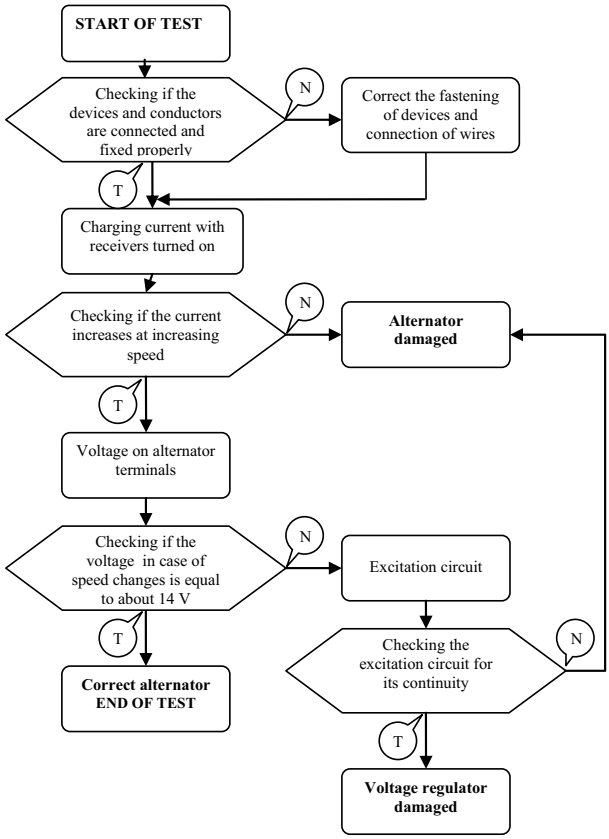

Fig. 1. Alternator checking status algorithm

Oscilloscope is most frequently used for testing of alternator technical condition in workshop practice. The testing consists in comparison of obtained curves with standard oscillograms [15, 16]. Figure 2 illustrates a correct curve occurring between B+ (positive) terminal of alternator and the frame and the curves for typical alternator damages are illustrated in Figure 3a, 3b, 3c, 3d.

The damage illustrated in Figure 3a is caused by the excitation winding discontinuity. However, the identification of this type of inefficiencies is problematic because similar curves occur in case of damages of all negative or positive diodes.

Figure 3c illustrates the curve caused by a damage (discontinuity) in one negative or positive diode and Figure 3d illustrates a curve caused by a damage in two diodes. However, in such cases it is possible to indicate a specific diode causing the inefficiency after the removal of alternator and additional tests.

The thermovision method proposed in the present article makes it possible to eliminate the aforesaid problems. Thanks to their advantages i.e. versatility and possibility of contactless temperature measurement, thermovision tests are perfectly suitable for the analysis of elements generating certain amounts of thermal energy. Therefore, it is possible to indicate the location of damage or an element causing the device inefficiency, i.e. an alternating current generator.

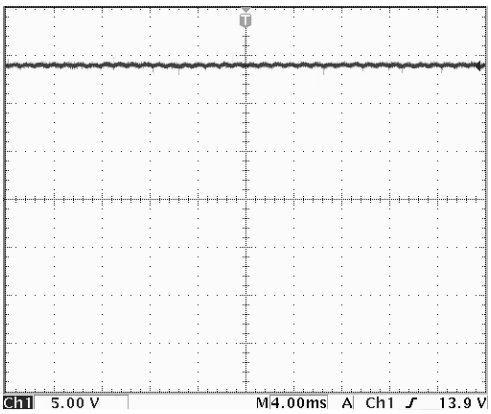

Fig. 2. Voltage oscillogram for an efficient alternator

THERMOVISION TESTS

The tests were carried out for the alternator parts which can be damaged in course of their routine operation as a result of ageing of elements or mechanical and electrical processes described above. The tests were carried out by means of ThermaCAM E45 camera manufactured by FLIR. The following electrical parameters of the alternator were applied in course of tests: U_{B+}=14,8 V, n=3000÷3500 RPM, I_{load}=10 A. The following criteria were followed in order to eliminate "the method errors" of thermovision measurements [5, 6, 7, 8, 12, 13, 18, 22, 23] significantly affecting the obtained results: emission factor was determined individually for each alternator (material) element under test, the impact of external IR radiation (lighting) sources was eliminated, the tests have been performed along alternator axis from the side of rectifying bridge (normal direction).

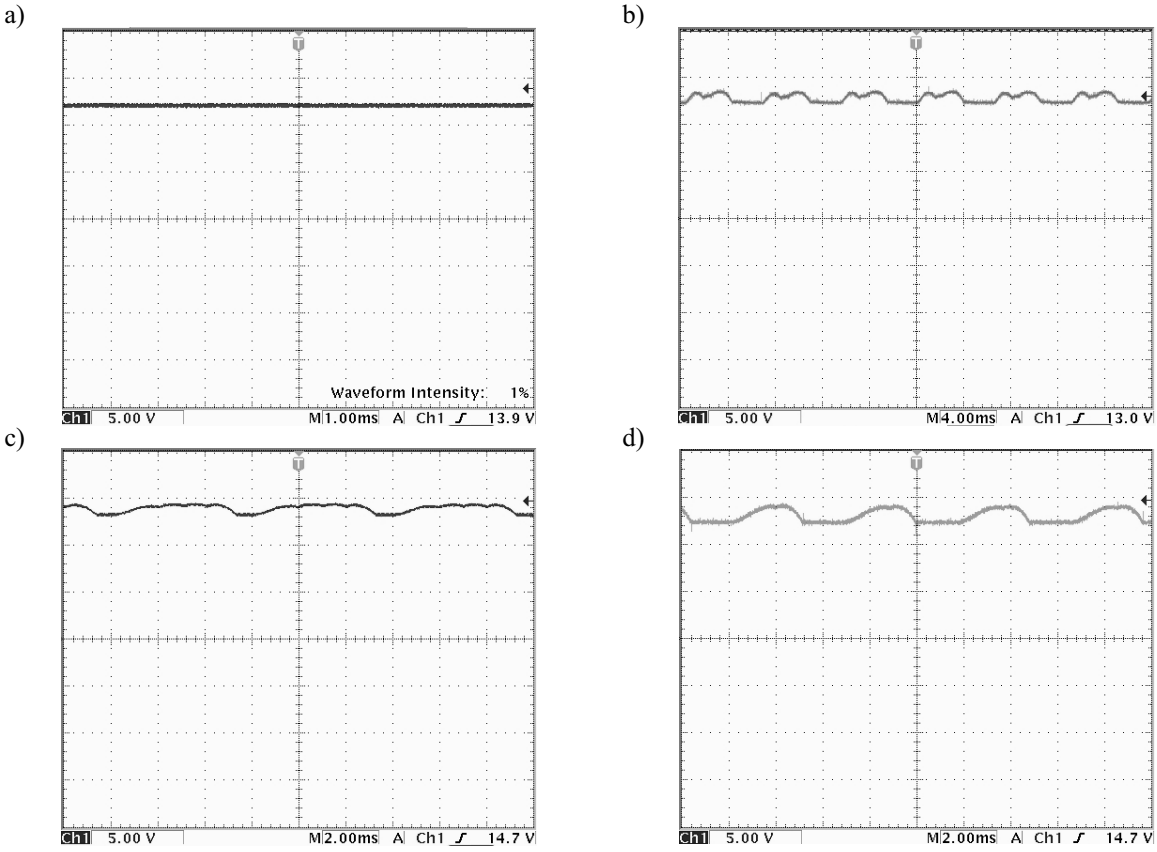

Fig. 3. Voltage oscillograms for a damaged alternator: a) excitation winding discontinuity, b) short – circuit in one bridge diode, c) discontinuity in one negative diode of the bridge, d) discontinuity in two negative diodes of the bridge

Figure 4 illustrates the thermograms obtained in the course of tests. As a result of discontinuity in magnetizing circuit located on the alternator rotor, no electromotive force is generated in the stator (armature). There is no current flow through diodes, therefore they are not heated (Fig. 4b). The temperature of brush holder (No 7, Fig. 4b) should be determined in order to eliminate the diodes damage causing similar diagnostic symptoms. This temperature should be similar to the temperature of the whole alternator. Thermovivion method makes it also possible to evaluate the brushes condition without necessity of their dismantling. When the alternator brushes are worn, their working temperature is reduced due to lack of "brushes – slip ring" contact and reduced value of current flowing through them.

In case of discontinuity in diode (No 6, Fig. 4c), thermovision measurements explicitly indicate the location of inefficiency. Moreover, by means of an appropriate computer assisted analysis, it is possible to determine if a specified diode will be not damaged soon. Table 2 represents the temperature differences for three (3) negative diodes, where: -4- stands for an efficient – brand new diode, -5- an efficient diode with wearing symptoms, -6- damaged diode.

Tab. 2. Temperature distribution in course of operation for individual negative diodes in rectifying bridge

Item	Time	Diode temperature -4-	Diode temperature -5-	Diode temperature -6-
-	(s)	(°C)	(°C)	(°C)
1	60	28,5	28,3	28
2	120	35,4	33,2	29,5
3	180	38,7	36,3	32,8
4	240	40,8	38	34,7
5	300	43	40,2	36,9
6	360	44,7	42,1	38,8
7	420	45,4	42,7	39,6
8	480	46,4	43,8	40,5
9	540	47,5	44,8	41,8
10	600	48,1	45,6	42,3
11	660	48,6	45,8	42,6
12	720	48,9	46,2	43
13	780	49,5	46,9	43,7
14	840	49	45,9	42,9
15	900	49,1	45,9	43

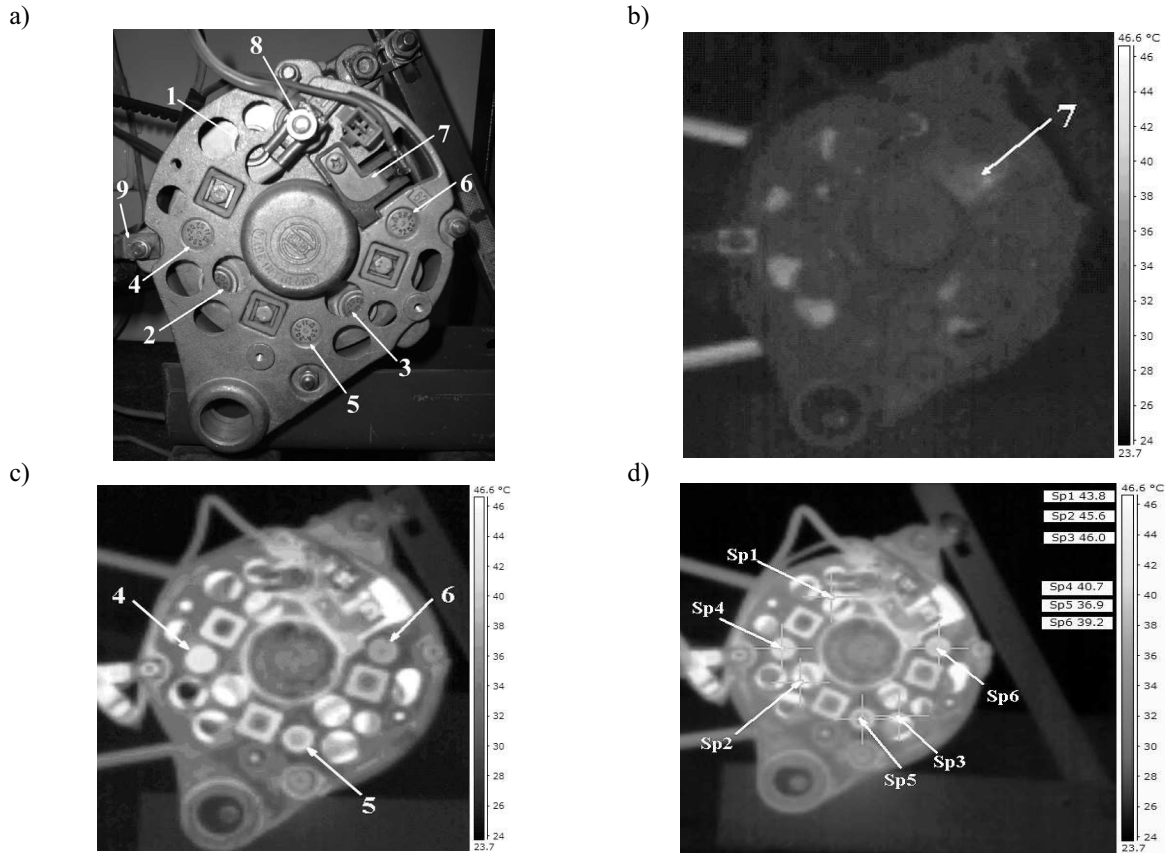

Fig.4. Alternator: a) object of tests, b) thermogram with excitation winding discontinuity, c) thermogram with discontinuity in one negative diode, d) thermogram of an efficient alternator; 1, 2, 3 – positive diodes, 4, 5, 6 – negative diodes, 7 – brush holder, 8 – positive terminal B+, 9 – frame terminal, Sp1-Sp6 – temperatures of main diodes

The difference of temperature achieved in course of operation of an efficient and inefficient diode is used as the criterion in order to qualify the diode as damaged (in course of thermovision measurements). From experimental test it appears that there is no difference in temperatures of efficient diodes exceeding 5%. In case of a damaged diode, regardless of its incorrect operation, the achieved temperature is higher than its value resulting from theoretical considerations as a result of heat exchange in the form of heat conduction and convection between damaged diode and other structural elements of alternator. Nevertheless, the difference of temperature between an efficient and inefficient diode (with discontinuity) is equal to 10% up to 20%. Therefore, it is possible to qualify an alternator diode as damaged.

CONCLUSIONS

Thermovision technique method presented therein can be used as the method supplementing the diagnostics in the scope of alternator technical condition and substituting conventional methods in certain cases. Its advantage consists in the possibility of an objective, non – invasive and contactless measurement. It is decisive criterion for the use of considered diagnostic method owing to difficult access to the generator or to its electric terminals (in some vehicles models). The conducted tests demonstrated that thermovision technique makes it possible to precisely indicate the location of an alternator element and to determine its technical parameters in an easy and quick way. Furthermore, using thorough computer aided analysis of the obtained results, it is possible to create database which could be useful in case of building the new design solutions for alternative current generators, selection of new materials, and consequently contributing to the increase of reliability and efficiency of alternators installed in motor vehicles.

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DIAGNOSTYKA ALTERNATORA Z WYKORZYSTANIEM OSCYLOSKOPU I PROMIENIOWANIA PODCZERWONEGO – PORÓWNANIE METOD

Streszczenie. Artykuł przedstawia nowatorską metodę badania stanu technicznego alternatora z wykorzystaniem kamery na podczerwień. Porównano w nim przedstawioną metodę z wykorzystaniem promieniowania podczerwonego z metodami konwencjonalnymi przedstawiając ich zalety i wady. Do badań termowizyjnych wykorzystano kamerę termowizyjną ThermaCAM E45 firmy FLIR. Badania zostały opracowane z wykorzystaniem oprogramowania komputerowego FLIR QuickReport. W artykule przedstawiono ponadto sposoby poprawy dokładności badań termowizyjnych w celu wykonania szybkiej i pewnej diagnozy.

Słowa kluczowe: prądnica prądu przemiennego, alternator, diagnostyka alternatora, kamera termowizyjna, obwód zasilania w energię elektryczną.