AN EVALUATION OF THE TECHNICAL STATE OF A STARTER USING THE HALL EFFECT - PART II

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Summary. The article presents the results of diagnostic investigations into electric starters installed on a real object and an aplication of spectrum analysis of magnetic induction.

Key words: diagnostics, damage, electric starter, Hall sensor.

INTRODUCTION

Car vehicles fulfil a range of tasks, the most important of which is undoubtedly an assurance of safety and comfort during travelling. Higher and higher requirements are being put as to their performance, durability and reliability, cost of exploitation etc. And the reliability of cars is the basic factor of exploitation safety as well as their production quality [Młynarski S. 2005].

The main systems of car vehicles, from the point of view of reliability, involve serial reliability structure, whose eligibility is dependent on the efficiency of all the elements, including those responsible for the start-up of a combustion engine.

The leading function during a start-up of a combustion engine belongs to an electric starter. Its condition decides on the work readiness of a combustion engine and, consequently, of a vehicle or a machine aggregate. A continous diagnostics of a starter promotes its optimal use as well as an unfailing engine's start-up. It also prevents premature damage.

To reach the basic aims of functional diagnostics, one should select the starter parameters which can optimally enable or facilitate making proper decisions concerning its technical state and allow for a prediction of an approach of its elements to a border state [Dziubiński M. 1990].

THE AIM OF THE PAPER

Ensuring a good technical condition and efficiency of the start-up system by frequent diagnostics and, when needed, an exchange of disabled elements is a way to ensure its long and reliable work. And the so far used practical diagnostic methods for electric starters in combustion engines have not allowed for an execution of full diagnostics of these devices directly in a vehicle. A precise examination of starters applying the methods used so far requires their removal from a vehicle, disassembly of aggregates and components and their detailed verification. Only following the realization of the mentioned actions, is it possible to start tests in idle gear and under load, carried out on testing stands

Thus, the present work aims at studying the possibility of an introduction of a new diagnostic method for electric starters carried out on real objects in the process of their work.

INVESTIGATIVE ASSUMPTIONS OF THE DIAGNOSTIC METHOD

The theoretical bases of the proposed diagnostic method were discussed in the first part of this work [Plizga 2008]. From the carried out considerations it results that car starters are electromagnetically strenuous electric machines, which means that their magnetic circuits are saturated. With regard to saturation of magnetic circuit, inductance of excitation winding is a variable value, dependent on changes of excitation stream values. Thus all the inductive parameters of car starter are non-linear functions of load current.

From the previous course of considerations it results that the system's electric factors have the greatest effect on the working parameters of a combustion engines's starter. Due to natural or accelerated wear the co-operation of feeding elements deteriorates. Hence, the starter's power and moment decrease, due to a weaker field influence of the stator's and armature's excitations. Using this fact, it is possible to assess the wear level of a starter's elements by taking measurements of its magnetic flux. In other words, the magnetic flux of a starter can be used as its diagnostic parameter.

It is possible to express the above-mentioned dependence as follows:

$$E_{A} = \left(R_{T} + R_{wz} + R_{A}\right) \cdot I_{T}(t) + \left(z_{T} \frac{\delta \Phi_{T}}{\delta I_{T}} + z_{T} \frac{\delta \Phi_{wz}}{\delta I_{T}}\right) \cdot \frac{dI_{T}}{dt} + c_{E} \cdot \Phi_{T} \cdot \omega(t)$$
(1)

where:

 E_{4} - electromotive force of uncharged battery,

 R_{T} - resistance of armature winding,

 R_{WZ} - resistance of excitation winding,

 R_{A} - internal resistance of battery,

 I_T - current of armature,

$$\left(z_T \cdot \frac{\delta \Phi_T}{\delta I_T} \cdot \frac{dI_T}{dt} \right) - \text{ decrease of inductance of district armature winding,} \\ \left(z_T \cdot \frac{\delta \Phi_{wz}}{\delta I_T} \cdot \frac{dI_T}{dt} \right) - \text{ decrease of inductance of excitation starter engine,}$$

 $c_{\rm F}$ - constant constructional of a starter,

 Φ_{T} - the main magnetic flux of armature circuit,

 ω - angular speed of armature.

Taking meassurements of a starter working extravehicular is possible during the course of test stand diagnostics, as discussed in the first work [Plizga 2008]. Elimination of overlapping faults in a combustion engine is made difficult in case of an employment of equipment for starters' diagnostics within the vehicle.

The measuring apparatus applied in the testing stand includes:

- a voltmeter for measurement of direct current voltage in the range from 0 to 40V,
- an amperometer for measurement of current in the range from 0 to 1200 A,

- revolution counter in the measuring range from 0 to 40 000 rpm⁻¹,
- mobile computer of PC class with an installed measuring card,
- a sensor of magnetic field in the measuring range to 0,25 T,
- a feeder of the Hall sensor.

For the measurement of magnetic induction intensity a sensor was used, whose functioning is based on the Hall phenomenon. This phenomenon results from the magnetic field's influence on the current in a semi-conductor.

Aiming at investigations into the usefulness of a diagnostic method for an assessment of starters installed in a car, a Hall sensor was fixed in the armature zone of a starter and during the starting-up of the combustion engine the courses of Hall voltage U_H were recorded on the output from the semi-conductor's connectors.

The site of Hall sensor's fixing was experimentally determined. The size of Hall voltage amplitude was studied at the sites of the fixing of the starter's pole shoe on the stator's external side in the three places: around the pole shoe, directly on the screw fixing the starter's pole shoe to its yoke as well as on border of bold head and yoke's hole. The largest intensity of the starter's magnetic field's stream was observed on the border of bold head fixing the pole shoe to the yoke's casing. This site was determinant of fixing the Hall sensor on the starter because of the strongest field's signal here.

The selected starter was 0 001 369 014 produced by Bosch, Germany, applied in the starting circuits of the Lamborghini Formula, Racing and Champion tractors. The popularity of usage in the Polish agriculture of the mentioned tractors and machine engines was considered during the choice of a starter for investigations into the new diagnostic method.

RESULTS OF INVESTIGATIONS AND THEIR ANALYSIS

The results of testing stand investigations into the studied starter using the Hall phenomenon for both an efficient starter and one with simulated damages are presented in Figs. 1-5.

An evaluation and verification of the electric starter's technical state were conducted after a comparison of Hall voltage courses for an efficient starter, treated then as the model ones, and for a faulty one. In order to exclude any possible unserviceability of a selected starter, its diagnostic evaluation by the Bosch method was conducted. For a simulation of typical mechanical or electric damages, some elements were disassembled (for example the brushes) and purposefully damaged (e.g. muffs of bearings were drilled to enlarge the clearance between the co-operating pair of shaft's pivot and bearing).

Considering the character of the running of starters as well as conditions of their work, the method of damage simulation was applied for investigation and the following kinds of damages were selected:

- friction between pole shoes and rotor (damages slide bearing),
- drossy or arid commutator,
- worn-out brushes,
- · simultaneous occurrence of all the mentioned damages.



Fig. 1. The course of changes of magnetic induction recorded for an efficient starter fixed in an engine



Fig. 2. The course of changes of magnetic induction recorded for a starter with simulated damage of sliding muffs fixed in an engine



Fig. 3. The course of changes of magnetic induction recorded for a starter with simulated damage of commutator fixed in an engine



Fig. 4. The course of changes of magnetic induction recorded for a starter with simulated damage of brushes fixed in an engine



Fig. 5. The course of changes of magnetic induction recorded for a starter with simultaneous occurrence of all the mentioned damages fixed in an engine

CONCLUSION

During the carried-out tests on a starter fixed in a real object, using the Hall phenomenon, interdependences were observed among all the simulated damages of starters and magnetic induction's intensity. These measurements illustrate the magnetic processes occurring in the starter, considering significant differences in the consumption of the provided current and the accompanying change of the device's technical state. The pattern of magnetic processes in the turned-on starter is also influenced by disturbances from the combustion engine being started, which can make the correct diagnosis of the machine damage somewhat difficult.

The mechanical processes in the starter cause an occurrence of electric phenomena around its poles. Due to the recording of magnetic induction in an efficient starter (Fig. 1) it is possible to observe a small alteration of this value. Then, differences in the magnetic induction tensions are caused by higher resistances of the starter's work during the compressing of flammable mixture in the cylinders of combustion engines. During the simulation of damage of sliding muffs and the friction between pole shoes and rotor (Fig. 2), alternating magnetic field's values are observed accompanied by an alternating consumption of the current from battery.

They also change the interaction between the magnetic fields of stator and rotor which results in an increase of the current's consumption from battery. As a result, an alternating magnetic induction occurs. Similar magnetic induction parameters can be observed during the simulation of damage of brushes and commutator's starter (Fig. 3-4). It results from arising disturbances in the winding at commutator's stuttering and faulty adherence of brushes to commutator (when the commutator is damaged), as well as in the case of periodical lack of brushes-commutator adherence, which is shown in Fig. 4.

Fig. 5 presents the course of changes of magnetic induction recorded for a starter with simulated simultaneous occurrence of all the mentioned electromechanical damages. The course of magnetioc induction is similar to the one recorded for an efficient starter, however, the difference is that the intensity of this induction is considerably higher with all the damages occurring simultaneously than with an efficient electromechanical system of a starter.

The conducted simulation investigations into an influence of electromechanical damages on courses of magnetic induction showed essential dependences among the simulated damages and intensity of magnetic induction, during research led on a real object even directly, when additional resistances of combustion engine movements create additional disturbances of Hall tension courses.

Summing up, an application of the Hall sensor to measurement of changes of magnetic induction depending on the state of an electric machine allows for a diagnosis of both the damages of an electric system, for example the brush-commutator, and the mechanical damages, for example the damages of sliding muffs. It is connected with the growth of a rotor's tractive resistances, and the involved higher consumption of current from a source of energy. Due to damages of this type, a growth of magnetic induction's intensity in a machine also occurs, which provides us with an image of an occurring damage through its recording.

REFERENCES

- Borsuk W.: 1984: Przebiegi elektromechaniczne w rozruszniku samochodowym. Rozprawa doktorska. Politechnika Warszawska, Warszawa.
- Ćwik Z.: 1994: Projektowanie systemów diagnostyki obiektów technicznych. IX Konferencja Naukowo-Techniczna "Diagnostyka maszyn roboczych i pojazdów". Bydgoszcz, s. 51-54.
- Dąbrowski Z., Radkowski S.: 1994: Wartościowanie celów diagnozy w procesie konstruowania wytworu. IX Konferencja Naukowo-Techniczna "Diagnostyka maszyn roboczych i pojazdów". Bydgoszcz, s. 55-60.
- Droździel P.: 2000: Metoda oceny eksploatacyjnej trwałości tłokowego silnika samochodowego z uwzględnieniem przebiegu rozruchu. Eksploatacja i Niezawodność 6/2000. Polskie Naukowo-Techniczne Towarzystwo Eksploatacyjne. Lublin, s. 41-49.
- Dziubiński M.: 1990: Diagnostyka funkcjonalna samochodowej prądnicy synchronicznej. Politechnika Poznańska, Poznań. Rozprawa doktorska.
- Dziubiński M., Kowal J., Pęcak M.: 1995: Badania diagnostyczne rozrusznika samochodowego z wykorzystaniem zjawiska Halla. Badania symulacyjne w technice samochodowej. Komisja Naukowo-Problemowa Motoryzacji. Lublin, s. 73-78.
- Dziubiński M., Krasowski E., Plizga K.: 2003: Koncepcja wykorzystania zjawiska Halla do prognozowania niezawodności obwodu rozruchu. Międzynarodowa Konferencja Motoryzacja i Energetyka Rolnictwa MOTROL'2003. Kijów, s. 41-48.

- Dziubiński M., Krasowski E., Plizga K. 2004: Analiza nadmiarowości w rozrusznikach samochodowych. XXXII Zimowa Szkoła Niezawodności "Nadmiarowość w Inżynierii Niezawodności". Sekcja Podstaw Eksploatacji Komitetu Budowy Maszyn Polskiej Akademii Nauk, Szczyrk, s. 81-88.
- Dziubiński M., Krasowski E., Plizga K. 2005: Metody rozpoznawania uszkodzeń rozruszników samochodowych. XXXIII Zimowa Szkoła Niezawodności "Metody badań przyczyn i skutków uszkodzeń". Sekcja Podstaw Eksploatacji Komitetu Budowy Maszyn Polskiej Akademii Nauk, Szczyrk, s. 106-117.
- Dziubiński M., Walusiak S. 1997: Analiza komputerowa stanu technicznego wybranych elementów rozrusznika. Konstrukcja, badania, eksploatacja, technologia pojazdów samochodowych i silników spalinowych. PAN Kraków. Zeszyt 11. Kraków. s. 177-182.
- Erd A. 1995: Wykorzystanie pomiaru chwilowych zmian prądu rozruchu do diagnozowania przestrzeni cylindrowych silnika spalinowego. III Krajowa Konferencja "Diagnostyka Techniczna Urządzeń i Systemów". Instytut Techniczny Wojsk Lotniczych. Warszawa, s. 35-40.
- Girtler J. 1994: Wiarygodność diagnozy jako prawdopodobieństwo podjęcia prawidłowej decyzji diagnostycznej. IX Konferencja Naukowo-Techniczna "Diagnostyka maszyn roboczych i pojazdów". Bydgoszcz, s. 83-87.
- Grzegórski J., Knopik L., Landowski B. 1994: Powtarzalność uszkodzeń elementów obiektów technicznych. IX Konferencja Naukowo-Techniczna "Diagnostyka Maszyn Roboczych i Pojazdów". Bydgoszcz. s. 95-100.
- Kamiński G., Biernat A., Szczypior J. 1982: Metoda pomiaru rozkładu przestrzennego wartości chwilowej indukcji magnetycznej w szczelinie maszyn elektrycznych. Przegląd Elektrotechniczny 8-9/1982, s. 210-213.
- Krupa S., Mitkowski S. 2002: Elektrotechnika. Teoria pola. Uczelniane Wydawnictwa Naukowo-Dydaktyczne AGH, Kraków.
- Młynarski S. 2005: Uszkodzenia podzespołów i niezawodność pojazdu. XXXIII Zimowa Szkoła Niezawodności "Metody badań przyczyn i skutków uszkodzeń". Sekcja Podstaw Eksploatacji Komitetu Budowy Maszyn Polskiej Akademii Nauk, Szczyrk, s. 347-357.
- Plizga K. 2006: Diagnostyka funkcjonalna obwodu rozruchu pojazdów rolniczych. Akademia Rolnicza w Lublinie. Lublin. Rozprawa doktorska.
- Plizga K.: An evaluation of technical state of a starter using the Hall effect-part I. Polska Akademia Nauk O. Lublin. Teka Komisji Motoryzacji i Energetyki Rolnictwa. Lublin 2008. s. 185-196

BADANIA STANU TECHNICZNEGO ROZRUSZNIKÓW PRZY ZASTOSOWANIU ZJAWISKA HALLA - CZ II

Streszczenie: W artykule przedstawiono wyniki badań diagnostycznych rozrusznika elektrycznego zamontowanego na obiekcie rzeczywistym przy wykorzystaniu analizy widma indukcji magnetycznej.

Słowa kluczowe: diagnostyka, uszkodzenia, rozrusznik elektryczny, czujnik Halla