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ELECTRIC MOTORS IN AUTOMOBILES

Summary. The low voltage electric machines are used for electric equipment of automobiles. This paper describes overview and some development trends of basic types of low voltage electrical machines, evaluation and elaboration of proposals and recommendation in this area. Brushless electric a machines in cars are one of the perspective types of low voltage electrical machines.

Key words: low voltage , electrical. machines ,development trends, recommendation starter, motor alternator, automatic ,measurement

1. INTRODUCTION

Electrical machines - not excluding the machines for motor vehicles -incorporate a complex of electrical, mechanical, and, recently, also electronic problems which have to be solved as a whole and virtually at the same time. This also includes problems of material, technology, operation and economy.

The number of electric motors in automobiles is forecast to grow by 200% over the next ten years. A key factor, stimulating this dramatic growth is the increasing use of electric motor technology to meet tighter standards for emissions, fuel economy, safety and reliability. As a result, new vehicle designs call for higher systems voltages, brushless dc motors, new types of alternators, starter – alternator combinations and all-electric auxiliaries for "drive-by-wire", "brake-by-wire" and "steer-by-wire" features. Accompanying this growth will be major changes in automotive technology, such as:

- ❑ *Increased use of electronics to meet today's requirements for emission control, fuel economy and safety*
- ❑ *The use of all-electric auxiliaries*
- ❑ *Wider use of higher system voltages, brushless dc motors and starter-alternator combinations*
- ❑ *New batteries and high power-density energy storage systems, such as capacitors and flywheels*
- ❑ *Practical development of electric and hybrid vehicles.*

The role of electrical machines in the automobile thus becomes of paramount importance. The purpose of this work is to provide an objective analysis of the new and advanced designs of automotive electric motors now under consideration. The presented work describes some results and conclusions in the following parts :

- ➢ ***Alternator***
- ➢ ***Starter Motor***
- ➢ ***Other Motor Types***

At the same time it is necessary for the presented work to include monitoring of development trends of automotive electrical machines as well as exploration and assumed application capabilities of brand new or even other types, first of all brushless machines (without commutators) etc.

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2. PROBLEM ANALYSIS

2.1. Electrical Machines in Cars

Electrical machines are used in many areas of life of the society and many types of them are produced in large quantities. Low voltage electrical machines, i.e. those fed from a source of a nominal voltage of up to 50 V, are one of the most employed types. These machines form one of the important parts of equipment of motor vehicles.

The branch itself seems to have been elaborated theoretically and experimentally rather well as the machines have been known and used for a long time. We sometimes forget that electronically controlled complex systems are indebted for their final effects to action elements which are mostly electric as they are easy to use and flexible. In order to be able to control even more complicated functions easily and efficiently, the action elements - electrical machines and electromagnets - have to be adapted and developed. At the same qualitative and ecological aspects and their mutual coherence become more significant. By using the term qualitative aspects it is necessary to understand first of all so called energetic parameters e.g. the performance, the efficiency or the power factor if need be, the rated output, the weight, the specific weight etc. Electric and magnetic field, noise, vibration, shocks etc. belong among ecological aspects that effect or may affect adversely the ambient environment. For the measurement of low voltage electrical machines, e.g. starters, alternators, and small motors for automotive accessories, an accurate determination of characteristics and parameters in the shortest possible time is required. In this case it is expedient to employ an automated system of measurement and evaluation of the measured data with the aid of a computer.

In each vehicle, there is a number of electrical machines used for various purposes. An alternator is the main supply of electric current, the combustion engine is started to the required speed by an electric starter, every electrical or electronic system includes an actuator, which is mostly an electric motor or electromagnet. Each type of machine has different output, dimensions, mass, position and type of connection to the driven device.

Electrical machines for motor vehicles, with the exception of the alternator, are still designed as classical direct current machines with a commutator and excited by an electromagnet or - for machines of an output of up to 1.5 kW - excited by a permanent magnet. They are powered from an accumulator of nominal voltage of 12 V or 24 V.

2.2. Brushless Electrical Machines in Cars

The commutator is a rather sensitive part of every direct current machine, which can be a source of a number of mechanical and electrical faults. The presence of a commutator is the limiting factor which significantly influences not only output and size parameters of these machines but also their operating reliability. The commutator must be given proper attention when it is produced. Any disregard of technological standards or requirements for the accuracy of the production of a commutator entails a degradation of the conditions of commutation and an increase in wear of the brushes and the commutator itself. To a certain degree, also the maximum speed of the rotor of an electrical machine with a commutator is limited. Therefore the present development of electrical machines - not only for motor vehicles - tends to use commutatorless machines, whose design and technology is simpler. This is made possible, among other factors, also by the development of electronic elements and circuits, which are necessary to control the above mentioned machines. This paper is partially focused on the application of this modern conception of electrical machines in the conditions of the electrical equipment of motor vehicles.

As an example, we will consider the possibility of using a motor with electric commutation for starting the combustion engine. It is clear that, due to the shape of the mechanical characteristic, torque and output power, efforts will be made to come close to the series direct current motor. This will reduce size, and weight of the motor since the electronic commutator would be placed outside the motor space. The way the starter is connected to the combustion engine would remain the same. Even this rough comparison shows that a plain substitution of the classical starter by a motor with the classical commutator is not possible at present. Up to now no application of these motors has appeared in the car industry. Like in all electronic equipment in cars, we cannot use this plain substitution - the design and technology of starters is so refined that minimum production costs and price can be reached. In this respect, a motor with electronic commutator is (several times) more expensive due exactly to the electronic part.

In the case of a machine with an electronic commutator, it would be possible to consider integrating the power supply and starter into one machine, which is an analogy of the previously used DC motor-generator. In this case, it would actually be an AC motor-generator. The electronic commutator would have to be designed so that it could enable motor action as well as let through electric current in the generator mode. With this solution, the economical aspect would be more favourable.

Another possibility for an application of this type of machines seems to be the case if we managed to place a commutatorless motor in the space of the combustion engine or use the flywheel of the combustion engine as the magnet system of a brushless motor or motor-generator. Not even in this case can we expect that a motor-generator with an electronic commutator could compete in price with the classical starter and alternator but the continuously dropping prices of semiconductor parts and their higher operational reliability could, in future, play a role in the decision making about a new solution. A more complex approach to the above problems is needed, which means that all aspects must be taken into consideration: the technical one (the electrical and machine part), the economical and operational ones.

3. ALTERNATORS

Alternators, as the main power supply in vehicles, appeared in operation on a large scale at the beginning of seventies as the so called „claw-pole" type. This design conception has been accepted by all the producers due to the technology of large series and mass production even though some drawbacks exist from the technical point of view such as large magnetic leakage in the rotor, the rotor being longer than the stator, low efficiency. Despite these (and some other) drawbacks, the claw generator design will probably be the leading conception also in the future. Since they were put into operation, the alternators have changed a great deal and they are still developing as regards the technology and power consumption due to the growing employment of electric motors and electronic devices. The requirements for the output keep increasing - from 400 W at the beginning to the present 700 W (at 14 V) with a view of 1.5 kW (i.e. 100 A nominal current). According to our information, Ford envisages an increase in the output of alternators to 3 or 3.5 kW in the year 2003 as a consequence of the growing employment of electrical and electronic equipment. Also the speed of the alternators increases. The original range of speed was maximum 10 000 /min with an allowed overtravel of up to 12 000/min. At present the alternators have 100A/14V, maximum speed of 15 000/min and overtravel of up to 18 000/min. This can be reached by either decreasing the mass and volume for a given output or by increasing the output for the same mass and volume.

The alternators are improved virtually in two directions: the output is increased, which means new designs or the losses are reduced, which means increasing efficiency. In this way the output taken away from the combustion engine can be reduced and fuel spared. Both directions of the development are the subject of research in the proposed project. Apart from that, it is necessary to deal with the possibilities and conditions for using a motor-generator, i.e. one machine used both as a starter and alternator.

The theoretical principles and inter-relationships discussed so far are reflected in the technical construction of modern alternators. Individual versions can differ from each other in certain details according to their particular application. At present, the claw-pole alternator with compact diode assembly is still being installed in the majority of vehicles, but the compact alternator is coming more and more to the forefront. The major design differences between these two alternator types are the compact alternator's two internally-mounted fans, its smaller collector rings, and the location of the rectifier outside the collector-ring end shield. Electronic regulator forms a unit with the brush holder for alternator mounting. Claw-pole alternators with collector rings feature compact construction with favourable power characteristics and low weight. These alternators are particularly suited for use in passenger cars, commercial vehicles and tractors etc.

Future trends for alternator are following:

- development of the compact alternator (with two ventilators),

- losses decrease for automotive alternator (low iron loss material, new ventilation),
- development of the alternators excited by permanent magnets,
- high-speed alternators,
- variable ratio drives,
- battery state of –charge-measurement,
- two speed drives,
- wider use of higher system voltages,
- starter - alternator combinations (for example induction machine).

4.ACTION ELEMENTS

4.1. Drive Motors

The role of action elements - with priority electric motors - in the automobile thus becomes of paramount importance. Basic point of view for these machines is maximum efficiency and maximum of power unit per mass. As action elements of electric motors are used - for example starter, water pump, fuel pump motor etc. It is characteristic of the electric drives in the present time motor vehicles that virtually one type of electric motor is used in them - direct current one with series, shunt or mixed excitation or with excitation by permanent magnets.

Electric drives in motor vehicles can be divided into two groups: non-regulated and regulated. The first group includes the starter, the second one then comprises the motors of the wind-screen wipers, air conditioning fans, window lowering, seat and external mirrors positioning, the electric fuel and cooling liquid pump etc. These two groups differ from each other by the output and type of the electric motors. In starters the output range is 0.5 to 9 kW, in the second group the outputs are of several tens of watts. The starter motor is almost always a classical direct current motor with either series or compound excitation or with excitation by permanent magnets. In the second group, a substantially wider choice exists - from the classical type of electrical motors, mostly with shunt excitation, over motors with permanent magnets of all types to motors with printed winding.

According to the information that is available and in our opinion the development of motors for car industry aims at using more permanent magnets above all for low outputs of up to 1.5 kW. This limit is given by the possibility of demagnetisation of the permanent magnet by the reaction of the armature with heavy currents. The problems of using permanent magnets in low output machines are mostly economical. Small motors excited by permanent magnets are used in large scale in automation devices such as servomotors. It is generally foreseen that by 2003 the use of electric machines with permanent magnets in vehicles produced in large series will be several times higher. In a modern car, several tens of electrical machines with permanent magnets are used.

The situation in the development of motors for the next five years shows that, for lower outputs, mostly electric motors will be used excited by permanent magnets this being mostly ferrite's, which are the cheapest now and, gradually, new materials will be used.

4.2. Starter Motor

Starter is one of the very important electrical machines in car, but it operates for very short time only. Therefore the development is focused on the still smaller and lighter machines. DC motors with series field winding, supplied from accumulator battery, are mainly used. Their properties are suitable for this purpose. At the present time two methods of power improvement per mass unit are tested. The first one uses the gear inserted between motor shaft and pinion and the second one applies permanent magnets instead of field winding. Permanent magnets can be used for small power - up to 2 kW - with regard to demagnetization problems. The prototype of this starter is now in production, so that we cannot present detailed information. In the development of starters the world manufacturers aim at using permanent-magnets for the excitation attempting to reduce dimensions and weight through increasing the speed of the starter motor (min. 3 times). The speed increase is made possible by introducing a reduction member (into the transmission) between the shaft of the electric motor and the starter pinion. Mostly a planetary gearing is used enabling to maintain the same diameter of the starter. In this context we point out that it is the use of the permanent-magnets for the starter excitation that enables to increase the planetary gearing gear ratio and thus the speed of the starter motor.

Starters with permanent-magnet excitation are reduced in weight by approx. 15%, they have smaller dimensions and lower winding losses. Permanent-magnet starters with a gearbox are reduced in weight by approx. 40% and have smaller dimensions by one third. According to literature[1] the weight of the ferrite magnets of a 1kW starter is about 220g with the total weight of the starter of 3,0kg. If the NdFeB material was used, then the weight of magnets would only be 68g and the weight of the starter would be 2,7kg. These data relate to a starter with a gearbox.

Lower output starters for passenger cars with the engine capacity of up to 1,9 litters use permanent-magnets in their exciting system without having any gearbox since the manufacture of the latter is demanding technologically and its cost per output would be too high. It is only for the engine capacity of 2 litters and more that a starter with a gearbox is used. In view of possible demagnetization due to armature reaction, for higher outputs over 2,0kW, classic starter motors with series or compound excitation will remain in use.

Results of development trends for starter are as follows:

- the use of new magnetic materials such as neodymium-iron-boron,
- the use of low iron loss materials,
- P.M. fields,
- geared starters,
- stop-start systems,
- the starter-alternator combinations,
- brushless DC motor as starter.

5. CONCLUSIONS

The major aim of the work is a research of the perspective types of low voltage electrical machines. The perspective types of low voltage electrical machines are above all :

- high speed alternators
- alternators and motors excited by permanent magnets (the use of new materials)
- geared starters
- small P.M. starters
- brushless electric machines
- starter-alternator combination.

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ANNEXES (FIGURE SUPPLEMENTS)

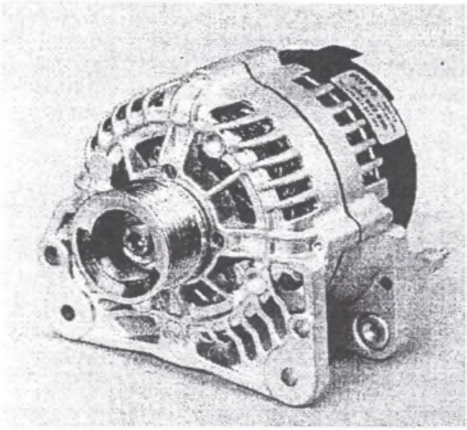

Fig. 1. Compact alternator MAGNETON 14 V, 70 A

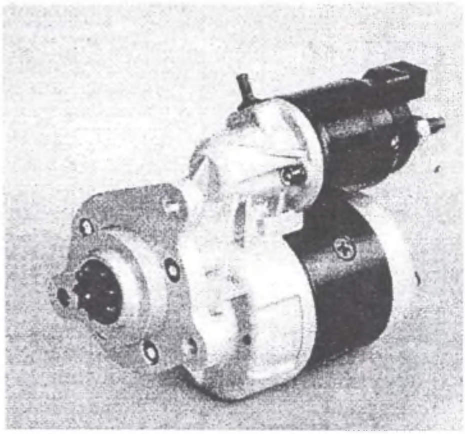

Fig. 2. Geared starter MAGNETON, 12 V, 1.0 kW

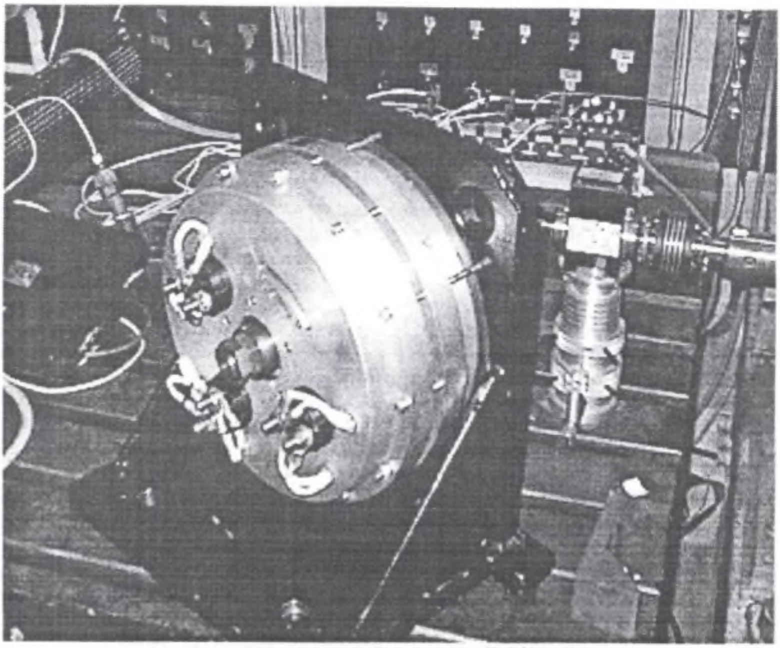

Fig. 3. Starter-alternator TU Brno and MAGNETON Kromeriz

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