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NEW STARTERS GENERATION

Practical operation shows that the overall reliability and durability of vehicles is affected, to large extent, by the starting characteristics of combustion engine, and also by the power and energy characteristics of the starting system. The presented work describes: overview of the starter types for passenger cars, contemporary starting system, new design concept of starters, requirements of the starting system.

1. INTRODUCTION

One of the most crucial and important part of our industry is made up by companies dealing with the manufacturing of motor vehicles and their accessories.

Out of the large number of tasks that the automotive industry currently faces, a very serious task appears to be to increase the reliability and durability of motor vehicles, particularly the utility types of vehicles. Requirements for the durability of, for example, engine electric accessories such as 250,000 km in operation or 6,000 hours in operation are not currently an exception. These requirements are increasing, in particular with relation to a higher intensity of car utilization, which again results from the present fuel and energy situation.

Practical operation shows that the overall reliability and durability of vehicles is affected, to large extent, by the starting characteristics of combustion engine, and also by the power and energy characteristics of the starting system. The starting system means a starter, electromagnetic switch, and storage battery.

Selecting the type and size of starting system must be based on the general requirement, i.e. an assurance of reliable starting of the engine under the given conditions of operation. This is then followed by the questions of size and weight of the system, its price, etc.

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2. CURRENT CONSTRUCTIONS STARTERS OF PASSENGER CARS

The starters as an independent constructional unit used for starting the internal-combustion engines (both spark-ignition and compression-ignition engines) consist of the following main parts:

– **electric motor** to change electric energy supplied by the starting battery to mechanical, i.e. rotary power,

– **electromagnetic switch** to ensure that the pinion is released from a standstill to the working one, and to connect the main current circuit of the starter,

– **release mechanism** to transfer the force from the electromagnetic switch to the freewheel,

– **freewheel** to transfer the rotary moment of the armature to the flywheel gear ring, and simultaneously to protect the armature against damage due to excessive revolutions at starting the engine

– **front (load) cover** with a respective flange to fix the starter to the engine or clutch casing, and to ensure a proper standstill of the pinion (sufficient distance of the pinion gear face from the flywheel gear ring face).

![Fig. 1. Starter without reduction gear](image1)
![Fig. 2. Starter with reduction gear](image2)

2.1. DESIGN OF THE ELECTRIC MOTOR EXCITATION

– Starter with stator winding excitation

– Starter with excitation by permanent magnets (PM) of ferrite type

– Starter with excitation by permanent magnets from rare earth elements, i.e. SmCo or NdFe

**STARTER WITH ELECTROMAGNETIC EXCITATION**

The conductors of exciting coils are made from Al or Cu profiles, either insulated (using enamel, wrapping, eloxal coating and painting) or bare wires with inserted insulation (cardboard) and subsequently impregnated.
This design featuring no reduction is represented by the starter, series $\varnothing$ 92 mm that was made by MAGNETON until 1994. (Fig. 1)

The latest designs are based on the use of an enameled Cu-wire having a diameter of approx. 1 mm, parallel n-wound (to ensure an appropriate cross section) directly on the coil body. The coils are locked between the pole and the frame using varnish. This design features a very good heat lead off towards the frame, and is likely to use the winding principle known in the technology of stator winding used for old alternators (STATOMAT automatic coiling machine). This design that has also no reduction gear is represented by the starter VALEO, series D7ES6.

Sometimes, parallel shunt coils are used to modify the torque-speed profile characteristic (they reduce the idle speed and increase the breakaway torque). This is referred to as a compound connection of the electric motor starter.

This design of stator connection is represented by the reduction gear starter, series 1 kW made by MAGNETON for ŠKODA Fabia cars (Fig. 2).

STARTER EXCITED BY PERMANENT MAGNETS (PM) OF FERRITE TYPE
(INDUCTION IN AN AIR GAP OF APPROX. 0.4 T)

This excitation is used for the 4 and 6-pole designs so that the required performance characteristics could be achieved. It is necessary to monitor the resistance against demagnetization due to the armature reaction (short-circuiting Fe-shunts are used). At minus temperatures both induction and torque are subject to a drop, which is in conflict with the needs of the engine at cold start.

Nowadays, the starters excited by ferrites are mostly used for designs with internal gear, which enables to reduce considerably dimensions, and thus the weight under simultaneous maintenance of the performance parameters.

STARTER EXCITED BY PERMANENT MAGNETS FROM RARE-EARTH ELEMENTS, I.E. SMCO OR NDFEB (INDUCTION IN AN AIR GAP OF APPROX. 0.8 – 1T)

PMs based on Sm +Co are mostly used for special technical equipment in the area of servodrives and measuring instruments. Especially the PMs based on NdFeB = neodym + iron + boron belong among the prospective materials. Electric motors using these materials achieve a high efficiency and excellent parameters. However, the magnets based on NdFeB feature many limitations too. In addition to a high price, it is at first to mention the thermal dependence; they can be used up to a maximum temperature of 140°C. Besides, they are highly susceptible to corrosion, brittle, difficult to machine and get magnetized.
3. NEW DESIGN CONCEPT OF STARTERS

When making analyses of the development of starters with permanent magnets based on rare-earth elements (NdFeB) as used for the stator excitation of new 3-cylinder ŠKODA engines, it was found that the presented original concept employing a release mechanism and electromagnetic rotation of the pinion enables to apply the system of two-stage engaging, which was until now used only for the starters of large combustion engines, also for the passenger car engines. The reason is that safe rotation of the pinion shaft teeth along the flywheel gear ring face takes place at as early as armature currents that are comparable with the pulling-in current of the switch. This principle enables to achieve a quiet, comfort and controlled engagement of the pinion gear in the gear ring, and thus to minimize the wear of this set.

3.1. DESCRIPTION OF THE CONSTRUCTION

MECHANICAL ARRANGEMENT

The AXIAL starter construction features the axis that is common for the pinion (1), armature (2) and release solenoid (3) with switching contacts. The release mechanism is based on the principle of releasing the pinion (1) itself advantages of which have proven in the construction of the starter with reduction gear.

In addition, the starter features an original placement of the freewheel, i.e. directly on the rotor shaft. The use of permanent magnets based on rare-earth elements
(NdFeB) in stator winding, which enables to achieve small dimensions of the electric motor without using a transmission, represents quite a new design.

**WIRING DIAGRAM**

The attached illustration shows both the wiring diagram of the starter concerned and the method of its connection to the electrical system of the car.

The diagram shows that the starter uses a DC commutator electric motor excited by permanent magnets. This design brings certain advantages (no large exciting coils in the stator), but also disadvantages. These include a relatively small self-inductance of the starter electric motor influencing the rapid current rise at the moment of making the power contacts of the switch.

Fig. 4. Wiring diagram of the AXIAL starter

It starts pulling in the switch coil via the bridge, and pushes the pinion shaft with pinion gear over the push rod against the flywheel gear ring of the combustion engine. The force of the return spring of the switch core, the return spring of the starter pinion, inertia masses of moving parts, friction on contact surfaces, and partially the pressure of air pushed out by the moving core from the space between the core and the base plate of the switch are acting against the force of the solenoid. Simultaneously, the magnetic field of the armature gets excited by a current that is limited by the resistance of the pull-in winding of the electromagnetic switch, and the armature

4. CONCLUSIONS

Starter AXIAL with permanent magnets based on rare-earth elements (NdFeB) as used for the stator excitation of new 3-cylinder ŠKODA engines, it was found that the presented original concept employing a release mechanism and electromagnetic rota-
tion of the pinion enables to apply the system of two-stage engaging, which was until now used only for the starters of large combustion engines, also for the passenger car engines. The improvement of methods for calculating the resistance torque depends on analysis of measurements for engines of one type and similar output. It may not be possible to obtain a formula to be used for all engines, regardless of the type, number and arrangement of cylinders.

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Przedstawiono oryginalną koncepcję rozrusznika AXIAL z magnesami trwałymi z ziemi rzadkich (NdFeB), stosowaną do uruchamiania nowego 3-cylindrowego silnika ŠKODA, korzystającą z urządzenia rozruchowego i wirującego elektromagnetycznego zębnika.

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