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## STARTER UNIQUE CONCEPTION

### ROZRUSZNIK SPECJALNEJ KONCEPCJI

**Abstract:** 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.

#### 1. Introduction

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. And it should be realized that the necessity to fulfil these requirements has resulted in using the electric starting system practically for all vehicles.

Reliability and durability of electric starting systems is one of the basic factors leading to an economical operation and effective utilization of motor vehicles.

Czech industrial enterprises in collaboration with the Brno University of Technology, Faculty of Electrical Engineering and Communication have completed the development of a high-speed starter of the so-called axial concept.

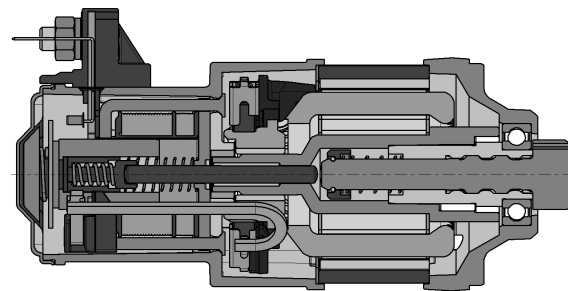
#### 2. AXIAL Concept

The AXIAL concept has undergone a certain development. The first product made in the above-mentioned concept was a 1kW starter, without a reducer (see *Fig. 1*). The need of saving costs for special magnetic materials and copper used in the electric motor, and also the need of a product with a higher rated power led to the development and a subsequent optimization of a starter with an AXIAL arrangement with a reducer, which enables using an electric motor with a higher rated speed and power and with a lower torque, and the necessary parameters are achieved by the reducer. This trend is apparent in all starter manufacturers. This design uses a planet reducer which enables a relatively great gear ratio, it fills the gearbox very compactly, torque is transmitted by several satellites (i.e. smaller forces act in the gearing) and, in addition, planet reducers are used suc-

cessfully in applications for high speed transmissions. To achieve the greatest possible compactness of the starter, the freewheel clutch is integrated directly in the so-called satellite carrier. The outlined project has undergone life tests and, in relation to the life test results, individual structural nodes have been optimized.

#### 2.1. Design of the AXIAL starter

This design, *Fig. 1, 2*, is very compact in relation to the build-up space "around" the starter; with regard to the concept used, the starter length is a certain disadvantage compared to competitive starters. However, there must be mentioned a weight saving by approx. 40% compared to products of comparable parameters. Other advantages of this concept include its high safety, i.e. covering of all "live" parts, two-step engagement of the pinion into the rim, high efficiency and resistance to demagnetization, particularly at low temperatures, waterproof design with a high corrosion resistance without the necessity of any surface protection.



*Fig. 1. AXIAL Starter*

As the development of new motor vehicles must respond to the increasing demands for their ecological operation, combustion engine developers are made to meet stricter emission limits (9/2008 Euro 5) with the engine construction and its accessories. A specific compo-

sition of the sucked mixture is used for starting a combustion engine – specific emissions are produced. It is apparent that there is a requirement for the development of a starter which will reduce the combustion engine start time and thus it will help reduce the amount of released emissions according to the relevant regulation. The industry in collaboration with the Brno University of Technology, Faculty of Electrical Engineering and Communication currently work on a high-speed starter project. This collaboration takes place within the purpose support from the Ministry of Industry and Trade for research and development in the IMPULS programme. Based on the maximum part unification with the 2kW AXIAL described above, the purpose of the high-speed starter is to reduce the starting time by approx. 30%.

To reduce the noise of the planet reducer gearing, starting possibilities have been determined for modifications of the gearing parameters and then those have been chosen from these possibilities that, based on theoretical assumptions, will have the largest impact on the gearing noise (use of materials with greater internal damping – plastics, gearing module change, etc.). The real samples made according to these theoretical assumptions were subjected to a noise measurement by an analyser on a test stand. It must be said that this piece of work could not be only simulated using software, because to describe the behaviour of the entire system, i.e. the starter body – planet reducer – electric motor (its vibration excitation effects), with a model is in the least more difficult, if ever possible, than making real samples which are then analyzed.

## 2.2 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. The electric motor is connected to the starting battery via the terminal 30.

The switch itself has two windings connected in parallel. The pull-in winding is connected in series to the electric motor of the starter, while the holding winding is connected to the starter frame. The winding of the electromagnetic switch is connected to the starting battery via the terminal 50 and switch box.

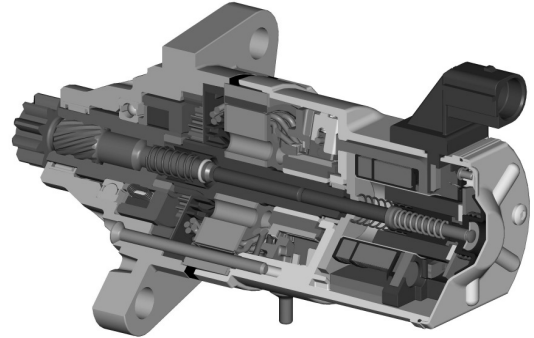


Fig. 2. AXIAL starter 2kW with planetary gear

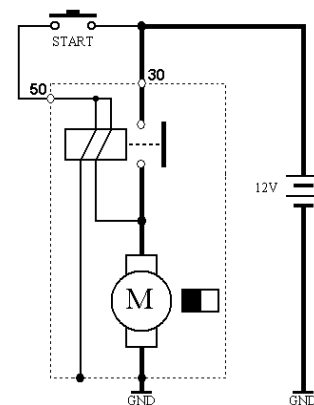


Fig. 3. Wiring diagram

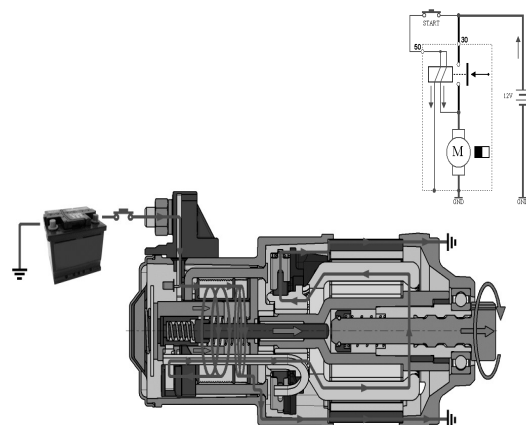


Fig. 4. Scheme of the starter function

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

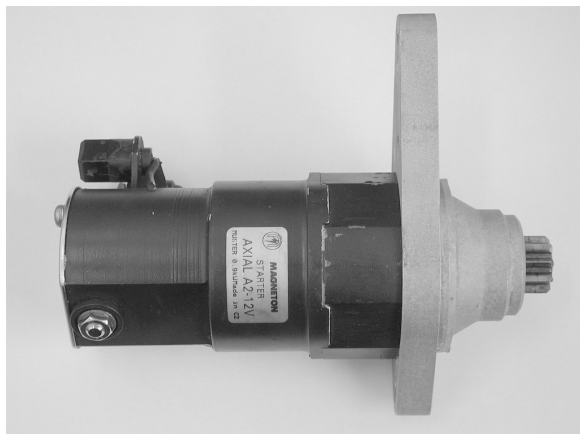


Fig. 5. AXIAL Starter Prototype (12 V, 1kW)

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 gets slowly rotated.



Fig. 6. Rotor of the AXIAL starter 2kW, lap winding

### 3. High-speed starter

The main stimulus for the development of a high-speed starter is to reduce the starting time and its optimization in contemporary combustion engines in relation to the tightening emission standards. The graph in Fig. 6 shows the course of combustion engine starting, first with a conventional starter (red), then with a high-speed starter version (blue). A competitive

starter of similar parameters was chosen as the reference sample (red).

The combustion engine starting took place under the same climatic and physical conditions. It is apparent from the graph in Fig. 6 that the time necessary for starting the combustion engine was reduced by approx. 0.1 sec and also a high speed of the combustion engine using the high-speed starter version can be seen.

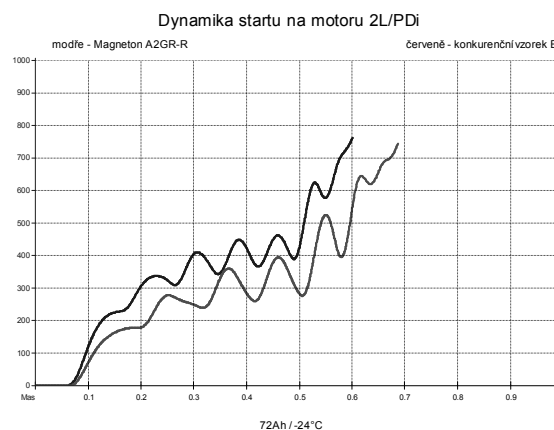


Fig. 7. Starting dynamics on engine 2L/P Di blue – AXIAL, red – competitive sample B

The graph in Fig. 7 shows the high-speed starter parameters converted to the crankshaft of the combustion engine. The so-called speed support for the combustion engine by this starter takes place to approximately 420 rpm of the combustion engine crankshaft, at a temperature of  $-24^{\circ}\text{C}$  and a battery capacity of 72 Ah, which corresponds to the internal resistance of a battery  $R_i=8.5\text{m}\Omega$ .

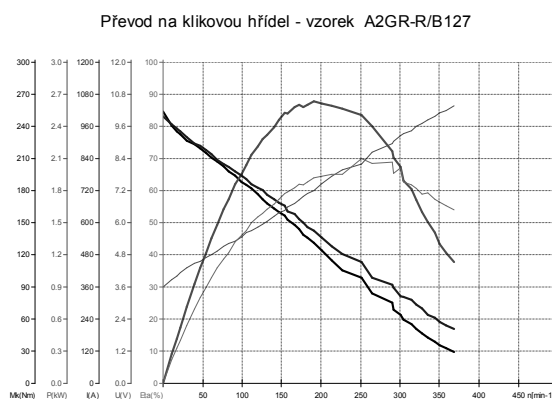


Fig. 8. Transmission to crankshaft – sample AXIAL

### 4. Conclusions

The unique, so-called axial concept of the starter brings advantages such as, among others,

a gentle engagement of the pinion into the rim. In principle, the situation can be described as follows: If the pinion is being engaged into the gear rim, it may happen that the pinion gearing will not engage into the rim gearing – the teeth collide.

The tripping mechanism of the axial concept also ensures reliable release of the contacts of the starter power circuit and also it ensures good dynamics of returning the starter pinion under worse climatic conditions when the ambient temperature is below the freezing point. In relation to the environmental friendliness of the product, it must be mentioned that the parts of the starter of this concept, which make up the outer shell, are made of aluminium alloy and thus the weight of the starter is lower compared to its rivals by approx. 40% and, in addition, the starter does not require any surface treatments.

## 5. Acknowledgements

Research described in the paper was financially supported by the Ministry of Education of the Czech Republic, under the project MSM 0021630516, the project of the Grant Agency CR No. 102/09/1875 and the project BUT Brno, No. FEKT S-10 -10.

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