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Design of starter motor using hef95-l technology

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ABSTRACT : *In this Paper, the parameters that are required to design the starter motor using HEF95-L technology were elucidated. Starting the internal combustion engine, operating sequence and the dimensions of starter motorwere discussed in detail. Further, this type of technology is usually utilized in marketing, designing and manufacturing of commercial vehicles (i.e., Lorries, tractors and buses) and not in conventional vehicles. There are various companies like Bosch, TVS Lucas and Mitsubishi which extensively manufacture flawless and efficient starter motors.*

I. INTRODUCTION

The starter motor is an electro-mechanical device which converts the electrical energy from battery into the mechanical energy in the motor. This mechanical energy is transferred through gears to the flywheel on the engines crank shaft. After the flywheel attains the required cranking it aids to start the engine. In general, the starting system has four main components. They are: The ignition switch or the push button, the starter solenoid, the starter motor
and the battery.

Fig.1. starter motor

There are two reasons that the automotive industry must convert to the use of high power density, high efficiencyand affordable electromagnetic devices for use in electrically powered automobiles. Firstly,emissions must be reduced to reduce air and water pollutionas well asglobal warming. Secondly, dependency on foreign oil must be reduced for both national security and cost consideration[3]. Concurrent with the need to reduce emissions and dependency on foreign oil supplies, customers for automobiles are demanding improvements in safety, comfort and quality of drive that can be provided by increased electrical power generation capability for electrical systems.

STARTING THE INTERNAL COMBUSTION ENGINE : A starter motor starts an internal-combustion engine by engaging its pinion gear in a ring gear that typically has about 130 teeth. On vehicles with a manually shifted transmission, the ring gear is on the engine flywheel, while on vehicles with automatic transmission, it is on the torque-converter housing. When in its resting position, the starter-motor pinion (which typicallyhas10teeth) is disengaged from the ring gear, but remains only a few millimeters away from it. When the driver turns the ignition key to the starting position, the starter motor first of all establishes the mechanical link between itself and the engine.

OPERATING SEQUENCE OF THE STARTER MOTOR
ENGAGEMENT : When the ignition switch is in the starting position, it completes an electric circuit that energizes the starter-motor solenoid switch. The magnetic field created by the solenoid coil draws in the solenoid armature, thus operating the engagement lever so that the pinion gear is moved outwards and comes into contact with the ring gear.

As starter motors for commercial vehicles have to produce high levels of torque, appropriate meshing methods have to be adopted in order to prevent excessive stress on the teeth of the pinion and ring gear. They ensure that there is sufficient overlap of the teeth before the starter motor delivers its full power.

TURNING THE ENGINE : When the starter motor begins to rotate, the transmission ratio between the pinion and the ring gear produces a large amount of torque acting on the crankshaft of the engine. The frictional resistance is overcome and the engine starts to turn over.

STARTING AND OVERRUNNING : As soon as fuel is injected/ ignited, the internal combustion engine starts to generate its own torque and, therefore, to increase its speed of rotation. After only a few ignition strokes, it is revving so fast that the starter motor can no longer keep up. The starter motor is thus overrunning. At this point, it is essential that the one-way or overrunning clutch disengages the pinion from the starter-motor drive shaft. By doing so, it prevents excessive wear and protects the starter motor from damage.

PRECONDITIONS FOR STARTING : The resistance to rotation of an internal-combustion engine, i.e. the torque required to turn it over, depends primarily on the engine capacity and the viscosity of the engine. The design of the engine, the number of cylinders, the ratio of stroke to bore, the compression ratio, the mass of the moving engine components and the nature of their bearings, as well as the additional drag from clutch, transmission and auxiliary drive systems also has an effect.

II. METHODS

DIMENSIONS OF STARTING SYSTEMS

A starter motor must satisfy the following requirements:

- Readiness to function at any time
- Sufficient starting power even at low temperatures
- Sufficient durability to start the engine many thousands of times
- Sufficient endurance to withstand the stresses of pinion engagement, turning the engine over, vibration and shock, the corrosive effects of damp and gritting salt, dirt, variations in temperature inside the engine compartment, etc.
- Lightness and compactness
- Maintenance-free operation.

PARAMETERS REQUIRED DESIGNING A STARTER MOTOR

The most important operating parameters are:

- Minimum starting temperature, i.e. lowest engine and battery temperature at which it should still be possible to start the engine
- Rotation resistance of the engine, equivalent to the torque required at the crankshaft in order to turn the engine and all connected auxiliary systems / drivetrain components at the minimum starting temperature
- Required minimum engine speed at minimum starting temperature
- Possible transmission ratio between starter motor and crankshaft
- Nominal voltage of starting system
- Characteristics of vehicle battery
- Impedance of electrical supply cables between battery and starter motor
- Speed / torque characteristics of starter motor
- Maximum permissible voltage drop in the vehicle’s electrical system for continued functioning of the motor electronics.

III. STARTER MOTOR FOR COMMERCIAL VEHICLES

Starter motors for commercial vehicles are nowadays generally fitted with a reduction gear in order to utilize the weight and size advantages compared with direct-drive starter motors. The use of lighter materials and optimized manufacturing methods has made it possible to reduce the overall weight by as much as 40%compared with conventional direct-drive starter motors. The area of application for reduction-gear starter motors with electromagnetic excitation is primarily diesel engines with capacities between 2.5 and approx. 16 *l*.

TYPE HEF95-L STARTER MOTOR FOR COMMERCIAL VEHICLES : The HEF95-L is the next larger model in the present range of reduction-gear starter motors. The area of application for this model covers diesel engines with a capacity of between 9 and approx. 12L.

DESIGN AND METHOD OF OPERATION: The flow of an electric current through conductors in a magnetic field produces a force. The effect of commutation is to create a constant. Torque M represented by the equation

$$M = c_1 \times B \times l\ \mathrm{Fe} \times d \times I \quad \ldots\ldots\ldots(1)$$

That is proportional to the current flowing, (I) the magnetic induction, (B) of the magnetic field, the length of the laminated core, (lFe) and d is the iron and diameter of the armature.

The machine constant, c_1, is derived from the number of poles and the characteristics of the armature winding.

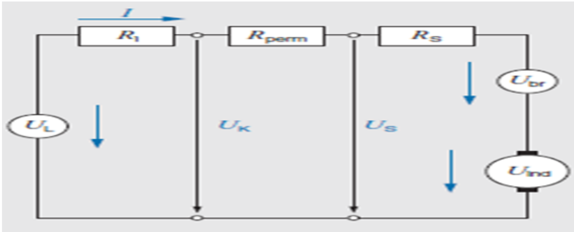

Fig.2. The induced voltage,

$$U_{ind} = 2 \times \delta \times c_2 \times B \times l\ \mathrm{Fe} \times d \times n$$

Where n is the speed of rotation of the armature, occurs in the armature winding. Due to the effect of commutation, this voltage appears externally as DC voltage. It is acting in the opposite direction to the supply voltage even though the polarity of the conductors on the rotating armature is continually changing. The machine constant, c_2, is determined as described above. The voltage at the battery terminals,U_K, is the product of the open-circuitVoltage U_L minus the voltage drop due to theBatteries internal impedance R_i. The voltage available at the starter motor $U_S$is further reduced by the voltage drop due to the supply cable impedance, R_{perm}. The voltage at the commutator is in turn diminished by the voltage drop;U_{br}due to the brushes.Approximately1.2 V is generally lost for each pair of brushes Regardless of the current.For positive and negative brushes combined therefore,U_{br}>>2.4V.The impedance of the startermotor itself is R_S.For the electric circuit as a whole, therefore,

$$U_L = (R_i + R_{perm} + R_S) \times I + U_{br} + U_{ind}$$

From which it follows that the speed can be represented by

$$U_L - U_{br} - (R_i + R_{perm} + R_S) \times I$$
$$n = 2 \times \delta \times c_2 \times B \times l\ \mathrm{Fe} \times d$$

The product of torque and speed is the power Output, Po, which is given by

$$P_o = 2 \times \delta \times M \times n$$

At the specified nominal voltage, the only technical parameters that can be varied in order to determine the power output are the impedance of the battery, the power-supply cable and the starter motor itself. The actual power output, P_m, delivered at the starter motor pinion is reduced even further by the Mechanical friction, V_R, and magnetization reversal losses, V_{Fe}, in the iron core so that

$$P_m = P_o - V_R - V_{Fe}$$

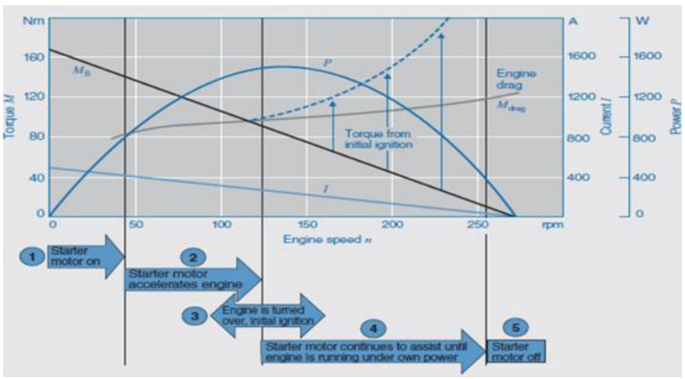

Fig.3. Phases of the starting sequence (schematic)

The HEF95-L starter motor is generally a closed-shield model in order to utilize the benefits of the design (e.g. greater resistance to environmental effects and greater adaptability with regard to fitting). In contrast with the less powerful Series HE95 starter motors, this model has an electrically operated, two stage pinion-engaging system in order to enable reliable pinion engagement and minimize ring-gear wear over the full service life of the motor despite the high dynamic forces at play. The two-stage pinion-engagement sequence is controlled jointly by the Type IMR pilot solenoid and the solenoid switch. The meshing spring is also integrated in the solenoid switch. A cutout spring ensures that the starter motor switches off if the starting sequence is aborted.

1st stage (preliminary stage) : A voltage signal (e.g. from the ignition switch or a control unit) activates the starter motor. It initially switches the IMR pre-control relay which is capable of switching the high current of approx. 150A required for a two-stage electrical system. That current then flows through a series resistor and a combined retracting and hold in winding. This firstly moves the overrunning clutch and pinion shaft outwards by operating the pinion-engaging lever. Secondly, a sufficiently high current can flow through the series resistor through the electric motor to start it turning before the main circuit is closed. As a result, the pinion can normally be fully engaged in the ring gear before the maximum current is applied to the motor by the closure of the primary-circuit switch. In exceptional cases, the pinion may not engage with the ring gear if the two gears are not aligned. In such cases, the meshing spring on the solenoid armature makes sure that the main circuit is completed before the pinion is fully engaged with the ring gear. The pinion-engaging sequence is then completed within a single stage.

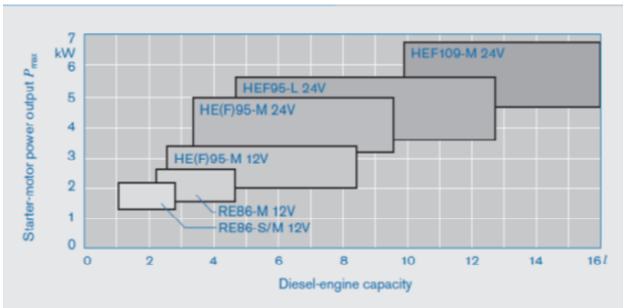

Fig.4.

2nd stage (main stage) : When the pinion has successfully engaged with the ring gear, the solenoid armature disconnects the circuit through the series resistor by means of a break switch shortly before it reaches its fully retracted position. Immediately after that, the main circuit is completed and the starter motor begins to generate its full torque output.

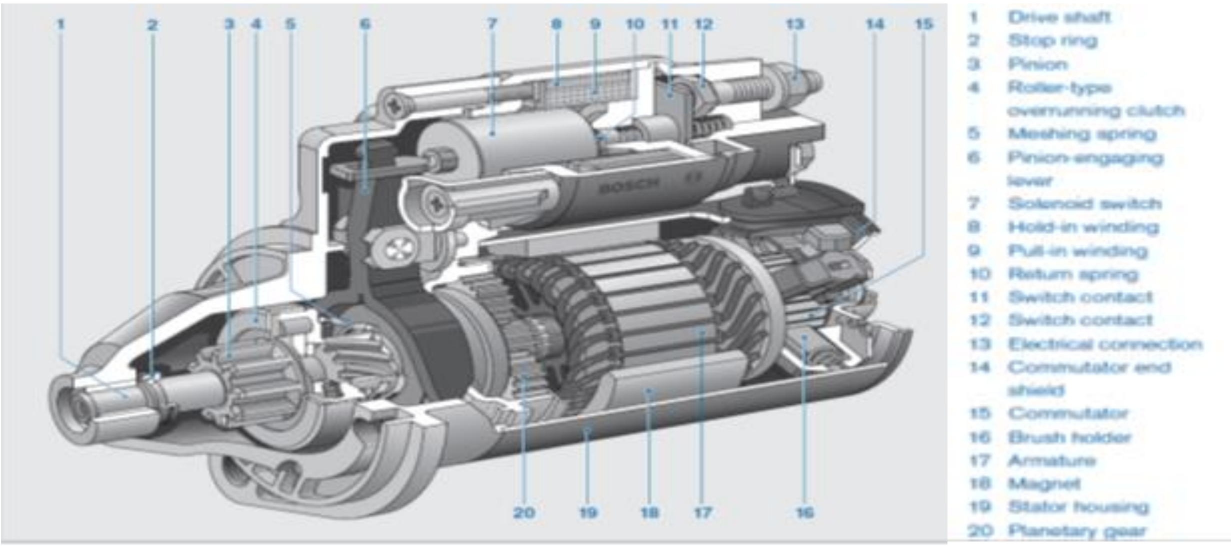

Fig.4. HEF (95) STARTER MOTORS.

IV. RESULTS AND DISCUSSIONS

The HEF95-L Technology is way superior to the other series of HEF and RE Technologies, because this technology is electrically operated with two pinion engagement sequences which enable reliable Pinion engagement and also minimize the stress acting on the teeth of the gears. By using lighter materials and optimized manufacturing reduction gear techniques it is possible to reduce the overall weight by as much as 40% as compared to other direct drive starter motors.

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