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## **Why the Induction Motor could be the better choice for your electric vehicle program**

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### **Abstract**

Low weight and high power density is a main focus in electro mobility.

The most common traction motors for vehicle applications are synchronous motors or induction motors whereas synchronous motors are preferred because of their advantage regarding power density and weight. But each of the motor concepts has its advantages and disadvantages.

In this paper it is shown that Siemens has managed to increase the power density of induction motors and simultaneously reduced the main disadvantage of the induction motor by optimizing some parts of the motor. With this adaption it is possible to reduce the weight and as a result of this defining parameter the induction motor has in summary more advantages compared with the synchronous motor. Therefore it can be the better choice for electro mobility

*Keywords: synchronous motor, induction motor, power density, efficiency*

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## **1 Introduction**

The use of permanent magnetic synchronous motors has not only advantages. The magnets are made of rare earth material and this material increased tremendously in costs and also needs higher efforts for safety measures. To take into account this issues an optimized induction motor by eliminating the disadvantages can be the alternative.

## **2 Details**

### **2.1 Functionality of a synchronous motor (Fig. 1)**

When the stator winding is energized with 3 phase voltage, it causes a rotating current and a magnetic field: The magnets of the rotor have a permanent magnetic field. The rotary field of the

stator interacts with the rotary field of the rotor, this results in torque. The motor shaft rotates.

Permanent magnetic Synchronous Motors (PSM) are normally designed as inner magnet systems for electric vehicle use. In this case synchronous motors build the magnetic flux with permanent magnets and for that reason an external magnetising current for the rotor is not necessary. Thus the losses in the rotor are minimized till nominal speed. Hence, the motor can be designed more compact and lighter.

When operating with field weakening as a result of the permanent magnet construction a field weakening current has to be implanted. This current influences the efficiency of the motor.

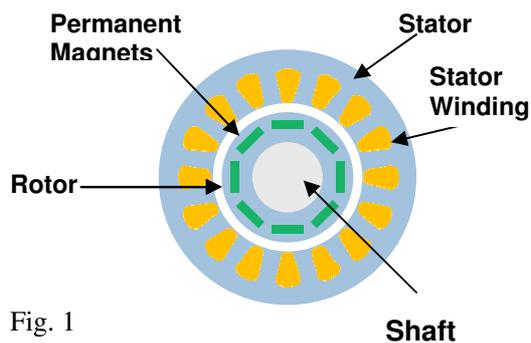


Fig. 1

Fig. 2 shows the flow of the magnetic field lines on an example of an 8-pole synchronous motor. As it is shown in the illustration the magnetic flux is acting mainly on the outer diameter of the rotor. The inner diameter and shaft are mostly field-free and therefore not coactive necessary for the magnetic field. This matter leaves room for weight optimization in this area.

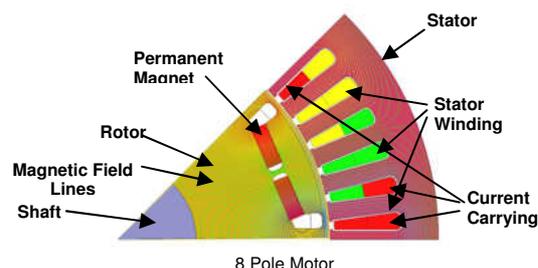


Fig. 2

## 2.2 Functionality of an induction motor

(Fig. 3) When the stator winding is energized with 3 phase voltage, it causes a current and builds up a magnetic field. The Stator rotary field induces voltage into the squirrel cage of the rotor. The induced voltage of the rotor causes current and torque. The rotary field of the stator interacts with the rotary field of the rotor. This results in torque. The motor shaft rotates.

Induction Motors induce the magnetic field within the rotor by implanting a short current in the squirrel cage. This concept effects higher losses in the rotor and causes higher heat and less efficiency. Depending on the material of the squirrel cage the losses are more or less higher. Standard low voltage motors use squirrel cages made of aluminium. Higher efficiency motors use copper because of its better electromagnetic

behaviour. This increases the power density but however there is a difference compared with permanent magnetic synchronous motors. Advantageously, on the other hand there are the lower costs and the higher robustness to be mentioned.

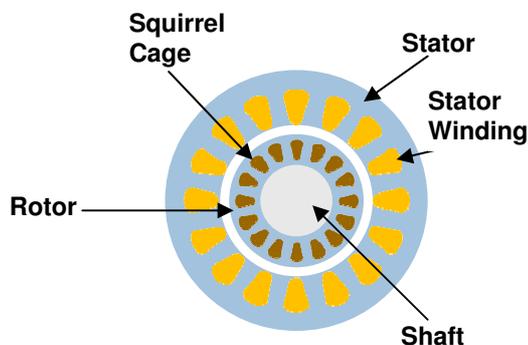


Fig. 3

Fig. 4 shows the flow of the magnetic field lines on an example of a 2-pole induction motor. Stator creates the magnetic field of the rotor. Higher power losses in the rotor  
→ Hot rotor  
Less current than rated at high speed and part-load

The induction motor needs the iron in the rotor to build a magnetic field for generating a torque in the air gap. Weight reducing action can not be done as it can be done with a synchronous rotor.

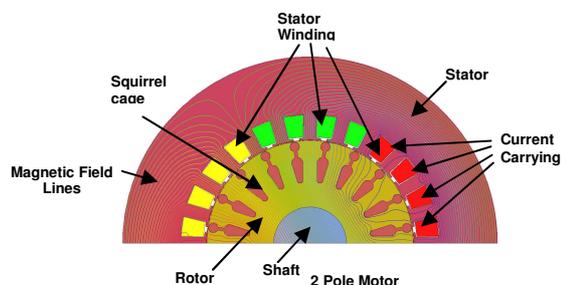


Fig. 4

## 3 Cost aspect

Synchronous motors use rare earths for magnets, prices for rare earths skyrocketed during the last years. Rare earths share of total value add for motor increased from 6% to 41% for electric motor suppliers between 2010 and 2011 (average).

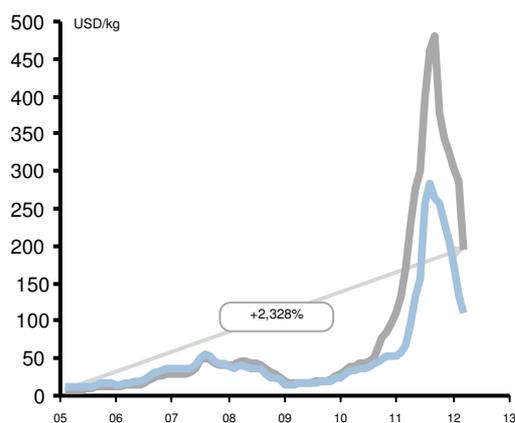


Fig. 5  
Fig.5 shows the trend of prices of Neodymium from 2005 till today

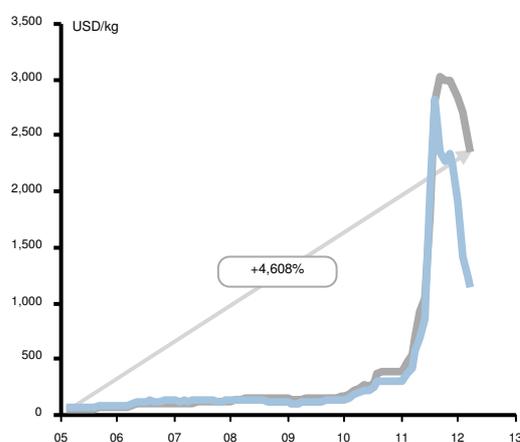


Fig. 6

Fig. 6 shows the trend of prices of Dysprosium from 2005 till today

## 4 Comparison of the motor concepts

### 4.1 Permanent synchronous motor

Advantages:

- + high torque density
- + high continuous torque
- + high efficiency
- + low power losses
- cool rotor temperatur up to rated power
- + wide range of constant power

Disadvantages

- high costs because of rare earth magnets
- efforts in field weakening necessary (field weakening current)

- high induced voltage when operating as generator
- safety aspects of hazardous material (magnets)
- higher efforts in manufacturing, service, recycling
- identification of the rotor position necessary
- higher system costs

### 4.2 Induction motor

Advantages:

- + high max. speed, high range of field weakening
- + low current at no load and part load operation
- + no rare earths necessary
- + robust design
- + no hazardous material,
- easy recycling
- + high safety with low effort
- + low production costs

Disadvantages:

- small torque density
- higher weight
- bigger volume
- high current at constant torque
- high power losses in the rotor
- hot rotor

## 5 Siemens Innovations

### 5.1 Innovativ rotor manufacturing

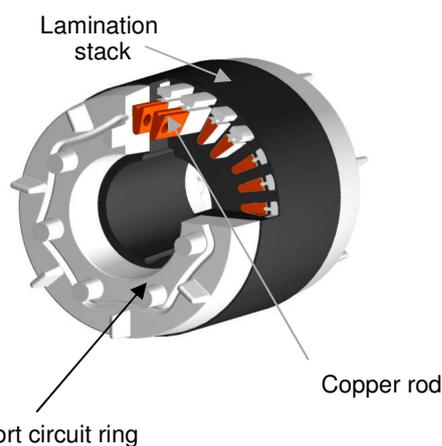


Fig. 7

Short circuit ring and connection with the copper rod made of die cast aluminum Fig. 7

Innovativ cooling system

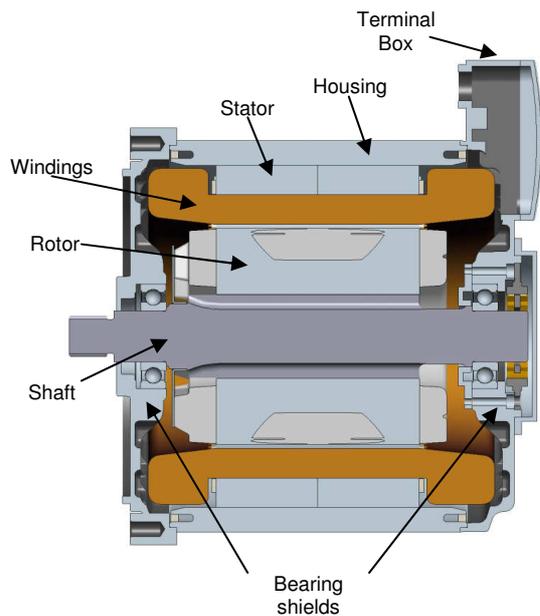


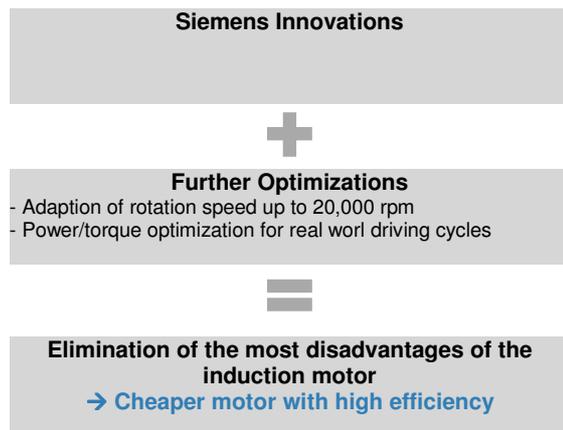
Fig. 8  
 ■ Cooler rotor with optimized cooling  
 ■ Higher power density

**Results:**

With optimized material and suitable cooling technique the power density and efficiency can be almost the same as with synchronous motors. The main disadvantages such as weight and installation space are comparable to synchronous motors and the induction motor gains in importance as a technical similar concept by a huge cost benefit.

**6 Conclusion**

Under normal conditions, with optimized performance and because of the better cost position the induction motor be the appropriate solution for electro mobility.



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