Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

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Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

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Background - Importance of improved ferrite magnets to the growth of electric vehicle

• There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations

• At present, performance/price factor compared to IC engine vehicles are holding back the growth of EVs
Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations

- At present, performance/price factor compared to IC engine vehicle are holding back the growth of EV

- The cost of batteries used in electric vehicles (EVs) has been falling fast and is almost certainly well below the estimates made by many analysts in the past decade\(^1\).

- A low cost powertrain could lead to affordable, efficient and performing EVs in market earlier than expected!

- Introduction of improved energy density ferrite magnet based PM motors is a possible solution to low-cost powertrain

Outline

- Background
- Specification of electric motor powertrain for two-wheeler
- Challenges in substituting rare earth magnet with ferrite in electrical machines
- Design details of ferrite magnet motor
- Mechanical assembly of motor
- Fabrication of the motor
- Conclusion
Emmo electric scooter

[Existing motor: Sintered rare earth permanent magnet motor]

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<thead>
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<th>Name</th>
<th>Unit</th>
<th>Value</th>
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<tr>
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<td>2</td>
<td>Maximum (Rated) vehicle speed</td>
<td>kmph</td>
<td>30</td>
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<td>3</td>
<td>Time to reach rated speed of vehicle</td>
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<td>4</td>
<td>Rated speed of motor</td>
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<td>5</td>
<td>Rated power of motor</td>
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<td>6</td>
<td>Rated torque</td>
<td>Nm</td>
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</tr>
<tr>
<td>7</td>
<td>Rated voltage</td>
<td>V</td>
<td>48</td>
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</table>
Challenges in substituting rare earth magnet with ferrite in electrical machines

- Residual flux density (Tesla) indicates amount of flux generated.
- Intrinsic coercivity force (kA/m) indicates resistance to demagnetization.

Legend:
- Ferrite
- Bonded NdFeB (RE)
- Sintered SmCo (RE)
- Sintered NdFeB(RE)
Challenges in substituting rare earth magnet with ferrite in electrical machines

- What others are doing
  - Motor without any magnets
    - Switched reluctance motors
    - Synchronous reluctance motors
  - Motor with magnets
    - New topologies to that allows putting more magnet in an efficient way such as axial flux machines, dual rotor machines

- Nanopyme motor topology and configuration offers
  - Low cost position sensing and simple controller
  - Easy to wound and easy to repair modular concentrated winding
  - Direct drive with no gears offers lesser components and improved reliability
Design details

Design constraints

- Number of stator slots: 18
- Number of rotor poles: 16
- Length of airgap: 0.4 mm
- Outer diameter of stator: 260 mm
- Gross slot fill factor: 50%
- Width of slot opening: 1 mm
- Depth of slot lip: 2 mm
- Depth of slot mouth: 2 mm
- Current density of coil: 4.5 $\text{A mm}^{-2}$
- Ratio of pole arc to pole pitch: 1

Optimised designs

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<tr>
<th>Design</th>
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<td>$P_{cu}$ (W)</td>
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![Diagram of design parameters](image)
Mechanical assembly of the motor
Fabrication of motor - stator tooth

Material: M400-50A
Fabrication of motor - stator coils
Fabrication of motor – tooth mounting assembly

Tooth holder

Shaft
Fabrication of motor – tooth mounting assembly
Fabrication of motor – Completed stator and rotor position sensor mounting
Fabrication of motor – Rotor yoke and magnet assembly
Completed motor on vehicle
Conclusion

- Introduction of improved energy density ferrite magnet based PM motors could improve the adoption rate of electric vehicles by offering low-cost powertrain

- DTU along with Nanopyme partners has fabricated and successfully completed first trial assembly of axial flux ferrite magnet motor for electric two-wheeler application

- In coming weeks DTU will fine-tune the motor assembly and integrate the motor to wheels of vehicle

- The on-board vehicle test of powertrain according to ISO 13064 standard is scheduled for October 2015. This will be followed by test bench evaluation of motor
Consortium

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www.nanopyme-project.eu

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