MQ1 based Redesign of Battery Blower Fan Motor

March, 2018

Benchmarking Process

- A battery cooling blower fan motor is procured from the market.
- The motor is benchmarked
  - Physical dimension benchmarking by measuring the following,
    - Weight of active material
    - Key stator and rotor dimensions
    - Winding pattern and conductor details
    - Magnet composition and magnetic characteristics of magnet
  - Performance benchmarking by measuring the following,
    - Closed circuit mid-airgap flux density
    - Cogging torque
    - No-load and load performance

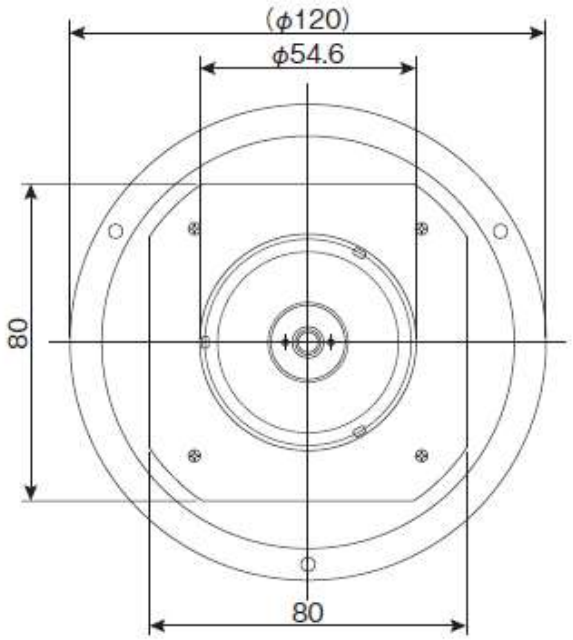
Benchmarked Motor

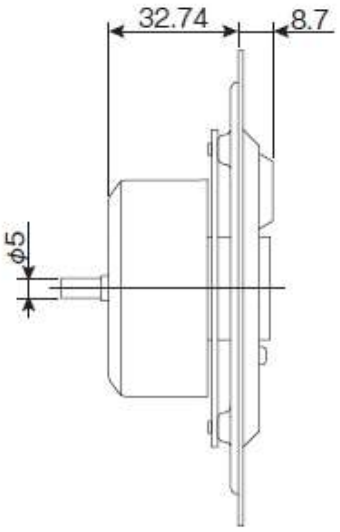
- End user: Toyota automotive
- Motor manufacturer: Shinano Kenshi
- Part number: G9230-76010
- Motor model number: DR-55310
- Motor type: Brushless (BL) DC motor

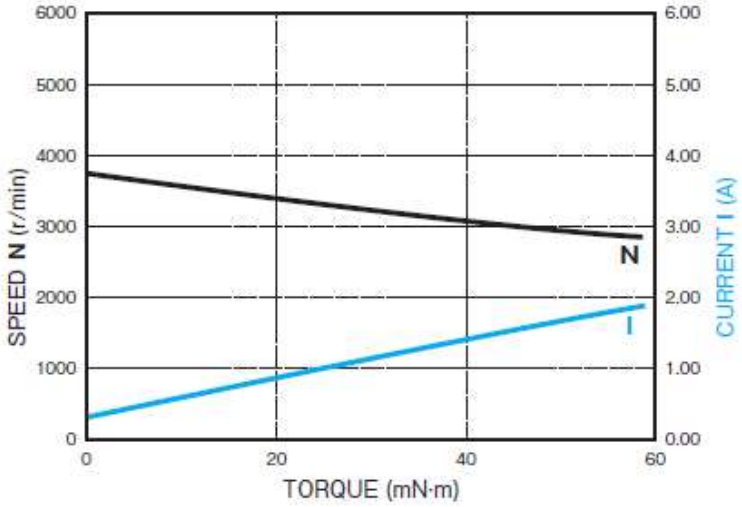
Benchmarked Motor Specifications (Published by Shinano Kenshi)

■ DR-55310

RATED VOLTAGE	RATED TORQUE	RATED SPEED	RATED CURRENT
DC 14 V	40 mN·m	3000 r/min	1.4 A

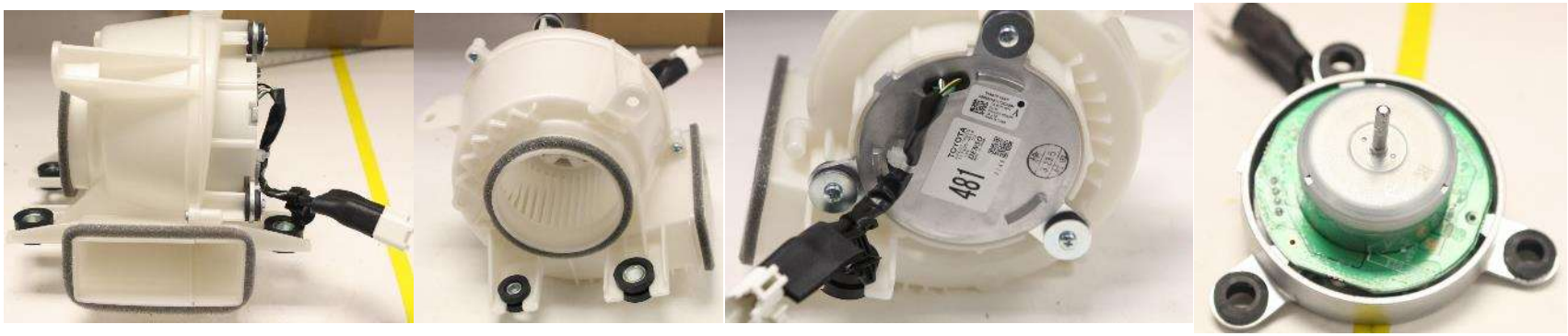


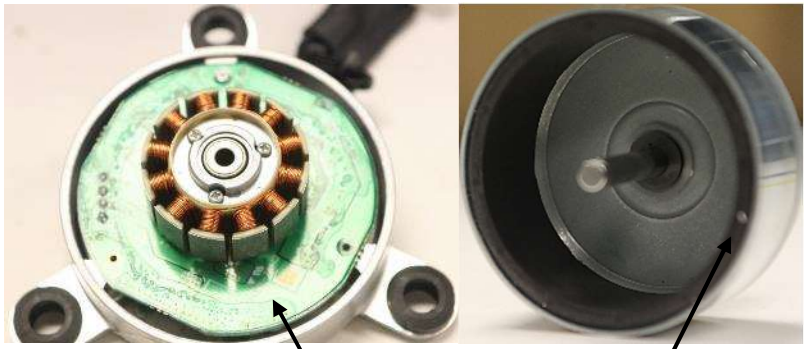




Reference: http://www.ap.shinanokenshi.com/products/bldc/pdf/p46.pdf

Motor Assembly and Key Weights



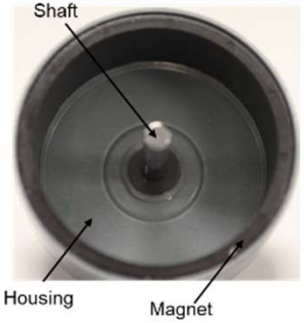


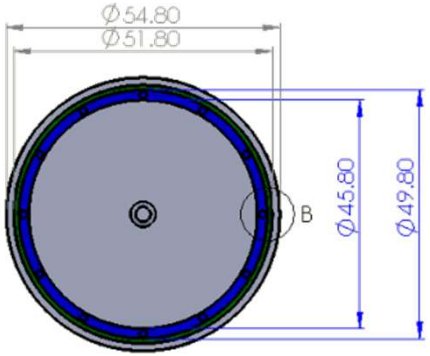
Motor controller

Rotor assembly (with magnet and pole housing)

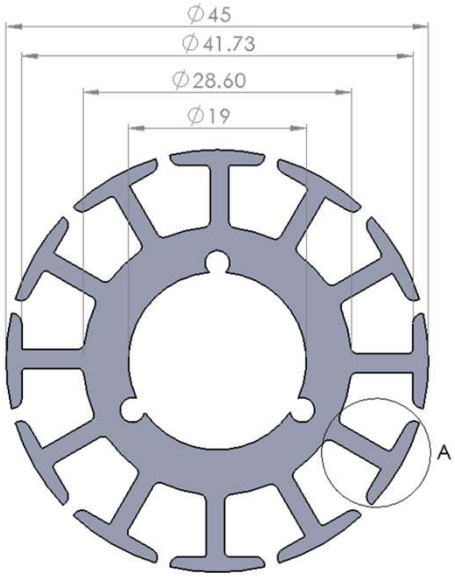
- Stator
  - No. of turns/coil: 23 turns
  - Conductor diameter: 0.45 mm (AWG 25)
  - Weight of copper = 16.74 g
- Magnet
  - Material: Injection molded ferrite
  - Number of poles: 10 poles
  - Magnet weight: 32.8 g
  - Density: 3.65 g/cm^3

Stator and Rotor Dimensions and Winding Diagram

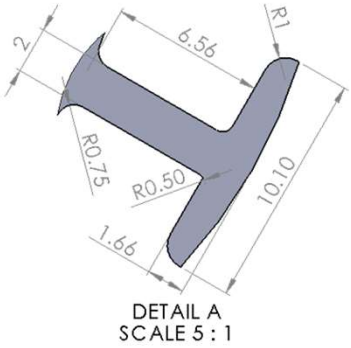


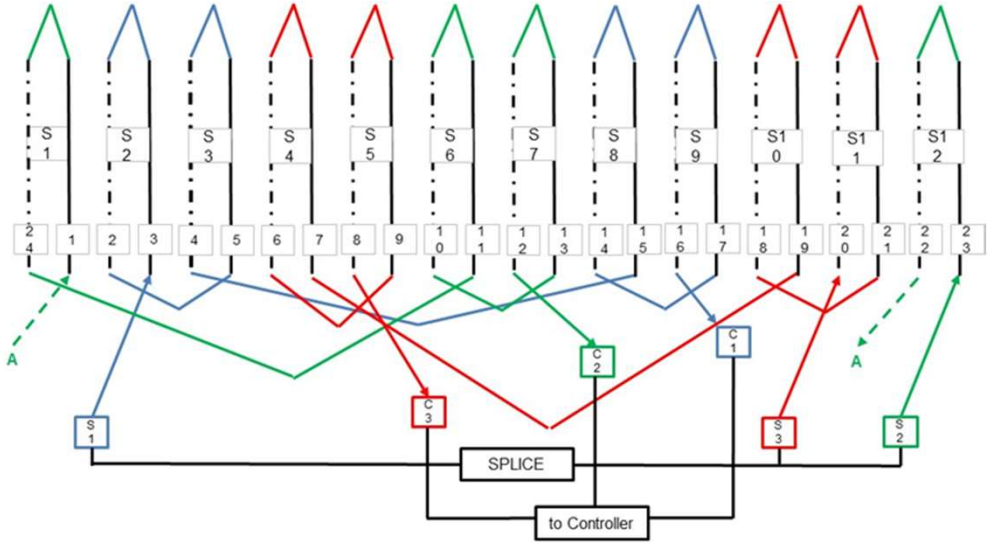


Rotor



Stator



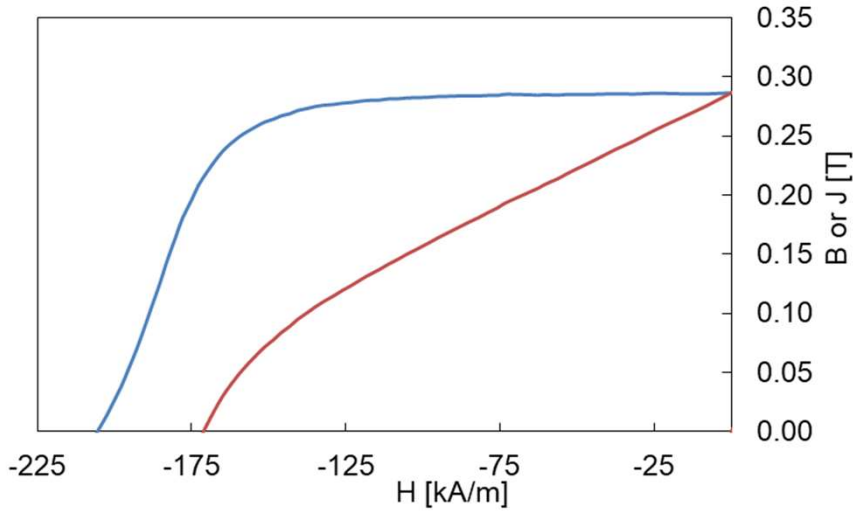


Winding Diagram

Magnet Analysis: B-H Characteristics

- Magnet Type: Sr-Ferrite

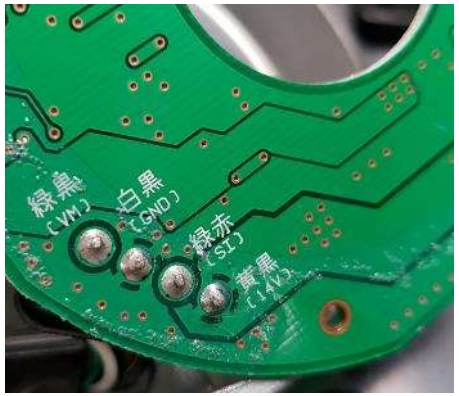
- B-H curve

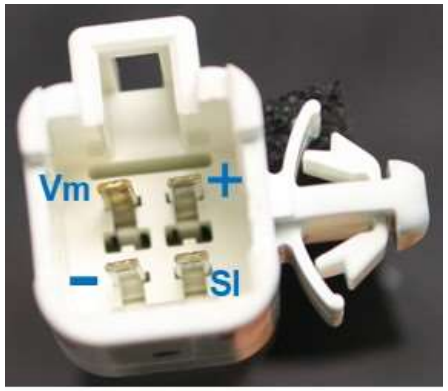


Magnet Characteristics

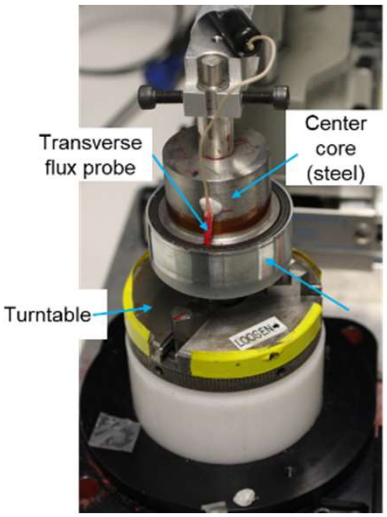
Magnetics	
Br	0.29 T
Hci	210 kA/m
Hc	170 kA/m
(BH)max	15.9 kJ/m^3

Connections to Control Circuit, Closed Circuit Flux Density and Cogging Torque Measurment

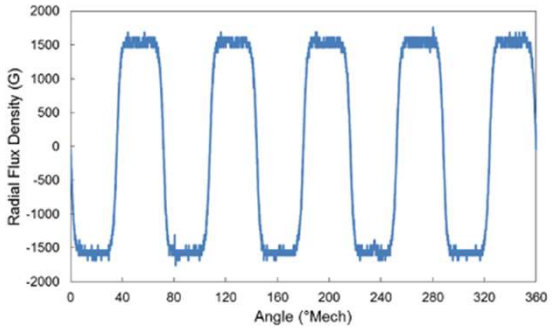


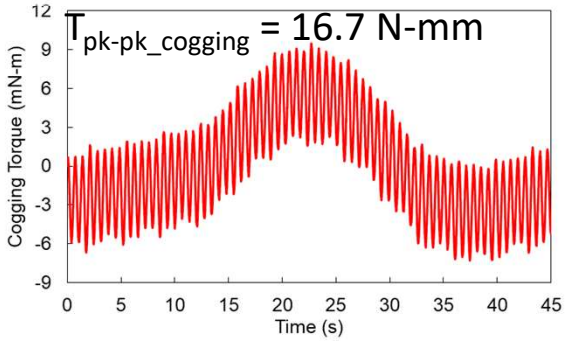


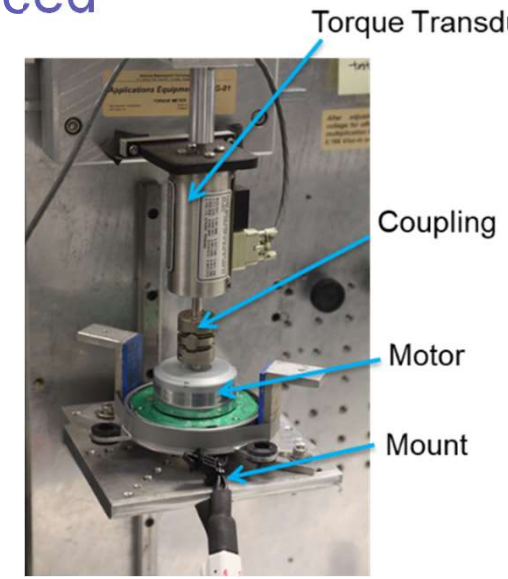
- Supply voltage = 14 V
- SI ⟹ Control signal and has to be set to high.
- Vm ⟹ Output voltage signal corresponding to motor speed



Closed circuit mid-airgap flux density measurement

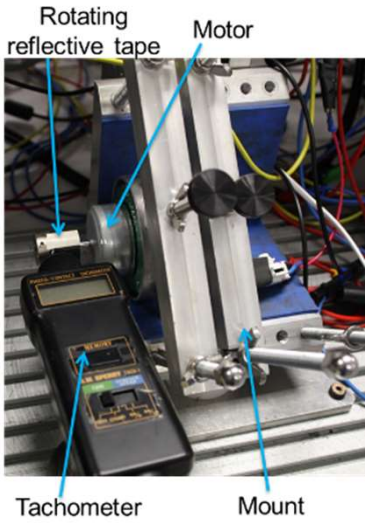




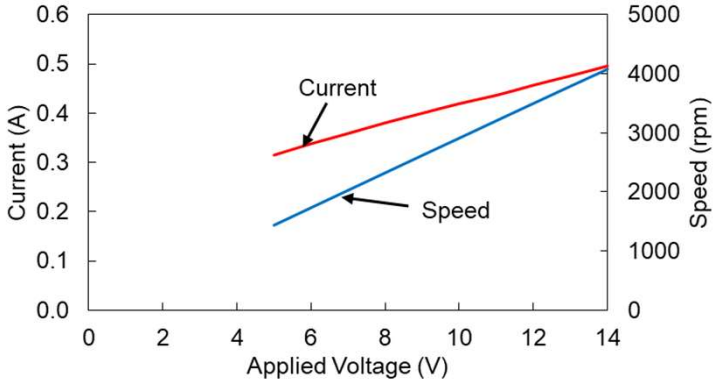


Cogging torque measurement

No-Load and Load Performance Measurement

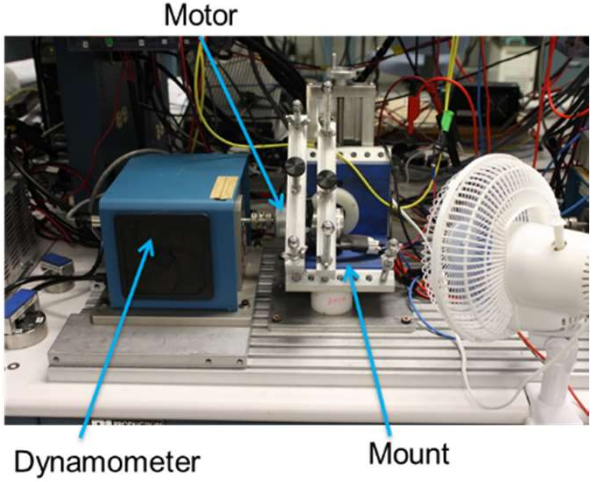


No-load Measurement

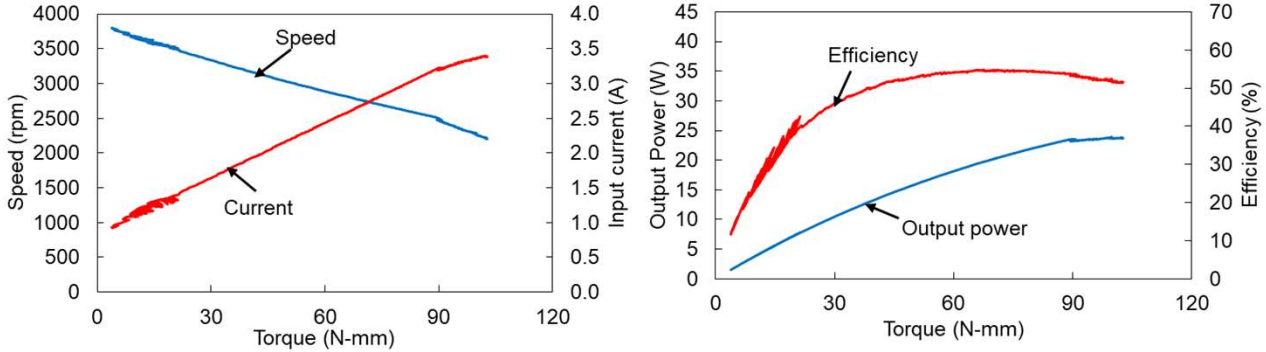


No-load performance of motor

No-load current (A)	No-load speed (rpm)
0.50	4079



Load Measurement



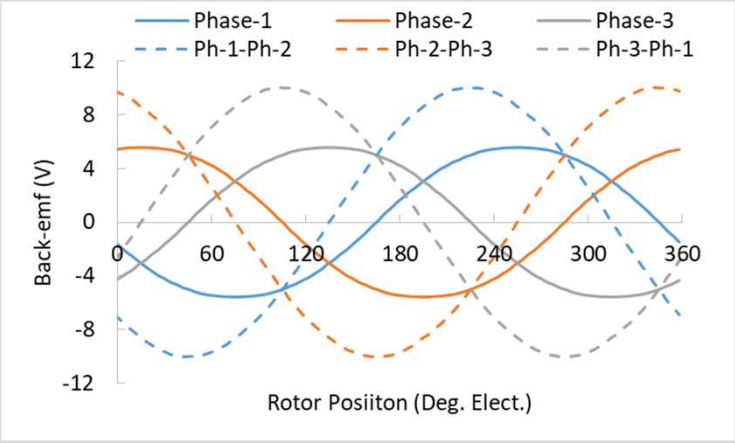
Motor's load performance

MQ1 based Redesign

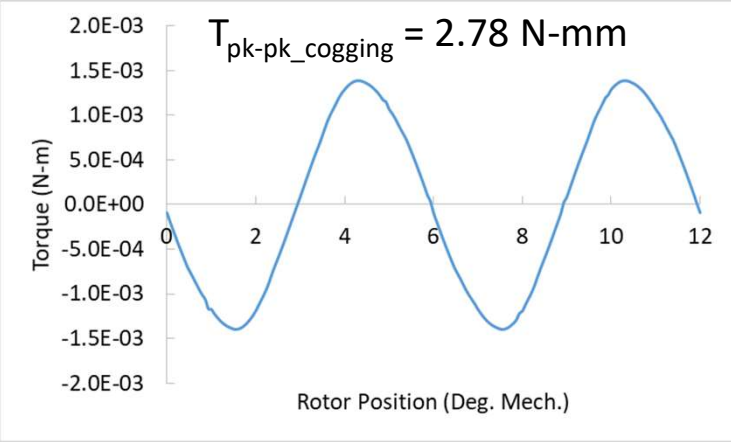
Approach to arrive at MQ1 Based Redesigned Motor

- Using the commercially available motor design software Motor-CAD, a motor is designed with compression molded MQ1 magnet.
- The motor is designed for an optimal active material cost.
- During the design following additional constrains are imposed,
  - The airgap for the redesigned motor is same as benchmarked motor
  - The conductor current density is similar or lower from the one in benchmarked motor
  - The slot fill is similar or lower from the one in benchmarked motor

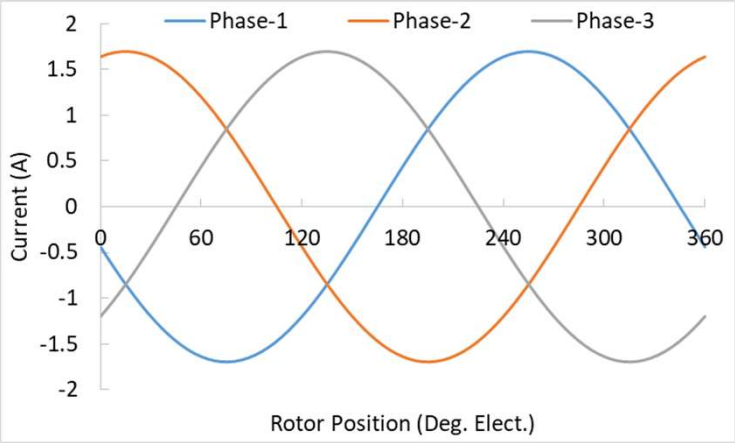
MQ1 Based Redesigned Motor: Performance



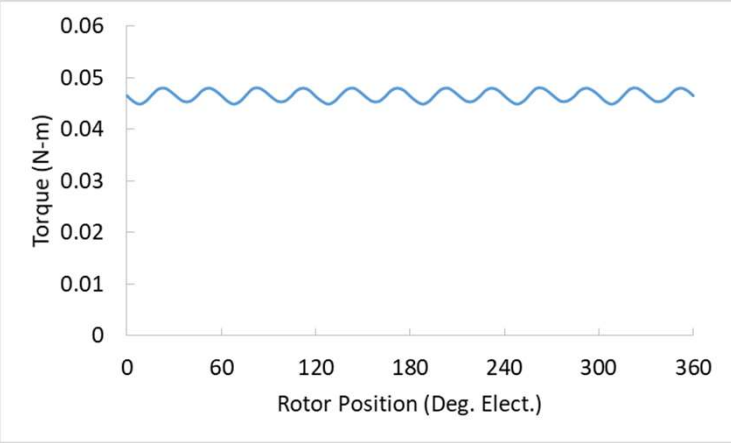
Phase and line back-emf @ 3000 rpm



Cogging torque

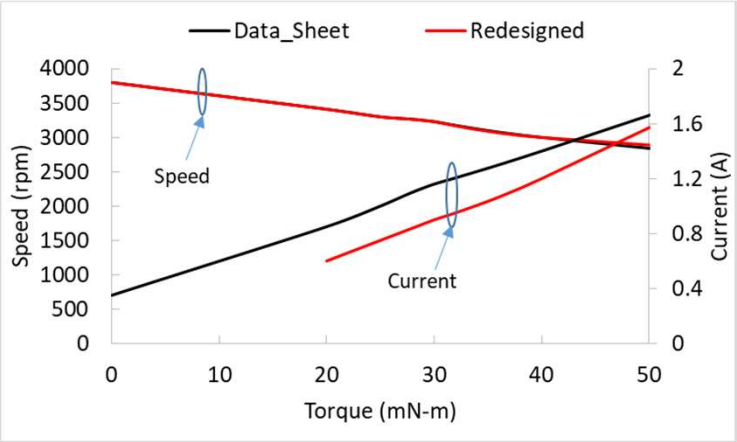


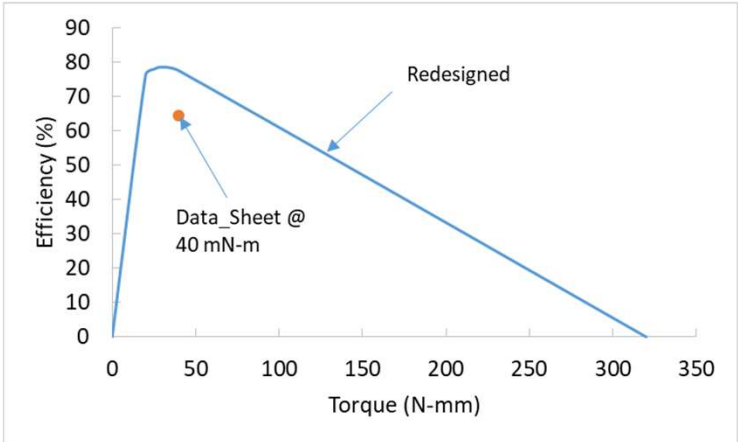
Motor current at T=40 N-mm @ 3000 rpm



Developed torque @ 3000 rpm

Comparison of Benchmarked and Redesigned Motors Performance

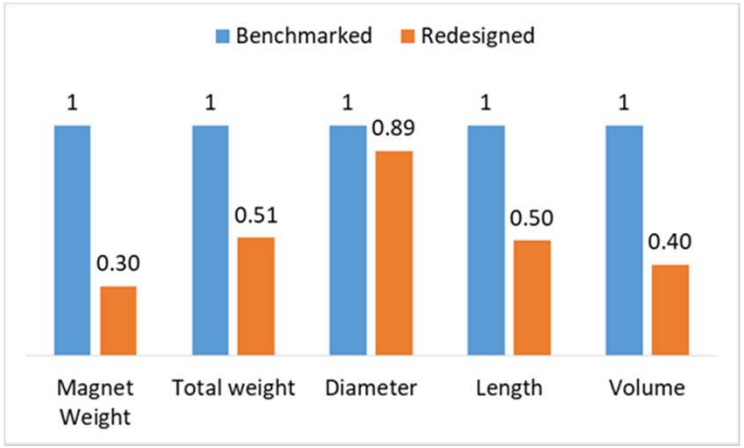




Comparison of benchmarked and redesigned motor performance

- MQ1 based redesign offers the enhanced motor efficiency,
  - 77.6% compared to 64.1% for benchmarked motor

Comparison of Benchmarked and Redesigned Motors Key Physical Dimensions



Comparison of key physical dimensions for benchmarked and redesigned motors

- MQ1 based redesign offers the following advantages,
  - Substantial weight and volume reduction
    - 49% Weight and 60% Volume reduction compared to benchmarked motor
  - For the same overall fan envelop a smaller motor dimeter offers an opportunity to increase the blade size and hence the possibility of increase in overall air flow.

Comparison of Key Physical Parameters for Benchmarked and Redesigned Motors

Parameter	Benchmarked	Redesigned
Magnet	Ferrite	MQ1
No. of pole	10	10
No. of slots	12	12
Skew angle (°)	0	6
Outer diameter (mm)	54.80	48.80
Length (mm)	20	10
Length of airgap (mm)	0.40	0.40
Weight of magnet (g)	32.80	9.91
Weight of copper (g)	16.74	14.30
Weight of motor (g)	182.11	93.33
No. of turns/coil	23	25
Coil Wire diameter (mm)	0.45 (AWG 25)	0.404 (AWG 26)
Current & efficiency (T= 40 N-mm @ 3000 rpm)	1.40 A / 64.13%	1.20 A / 77.59%

Observations

- MQ1 based redesign offers the following advantages,
  - Enhanced efficiency of motor
    - 77.6% compared to 64.1% for benchmarked motor
  - Substantial weight and volume reduction
    - 49% Weight and 60% Volume reduction compared to benchmarked motor
    - For the same overall fan envelop a smaller motor dimeter offers an opportunity to increase the blade size and hence the possibility of increase in overall air flow.
  - Negligible cogging torque when the magnetization with optimal skew is used

Questions? Want to know more? Collaborate with us?

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www.mqitechnology.com