Motor Design - Factors Affecting Size of Motors

Electric seats, electric tailgates, direct drive wiper motors, engine cooling fans, and grill shutter actuator are few examples from the passenger vehicle markets which benefits from the use of smaller and lighter motors. Understanding what impacts the size of the motor is crucial to design an efficient end application.

At Magnequench, our design team consists of motor designers and material scientists to help our customers answer many of the questions which help to translate into lighter and smaller products.

Design Challenge

Determining the size of the motor seems a simple concept, however achieving a balance between various geometrical parameters is critical for getting lighter, smaller and/or efficient motor.

In a conventional radial flux motor, the output of the motor depends on various physical parameters, these parameters are;

$$\boldsymbol{P_{out}} \propto \boldsymbol{B_{av}} \mathbf{ac} \boldsymbol{D^2 L N_s}$$

Where, $\boldsymbol{B_{av}}$ is the average airgap flux density, $\mathbf{ac}$ is the electrical loading (depending on the no. of turns/coil and current drawn by each conductor)

$\boldsymbol{D}$, is the rotor diameter and $\boldsymbol{L}$ is the length of the rotor

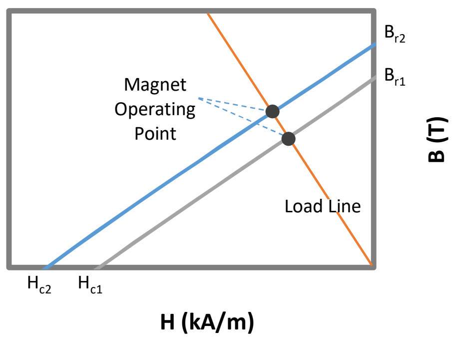
$\boldsymbol{N_s}$ is the rated speed of the motor

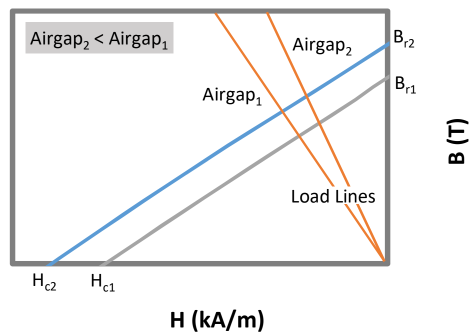
Factors affecting $\boldsymbol{B_{av}}$

Magnet material properties and the operating point of magnetic circuit (magnet operating point) determine the average flux density in an airgap. For the same motor airgap, higher magnet remanence (Br) will lead to higher $\boldsymbol{B_{av}}$.

A magnet offering higher Br reduces the volume of the magnet needed to achieve the desired flux in the airgap and thus enables sufficient space for windings without increasing the size of motor.

For the same magnet dimension, if the airgap length is reduced then the overall magnetic circuit will result in the higher magnet operating point and hence the higher $\boldsymbol{B_{av}}$.





Factor affecting the Electrical Loading (ac)

The ac depends on the number of turns and current carried by each coil. For a given current, the higher number of turns/coil will result in higher ac and a smaller motor. Similarly, for the same (number of?) turns/coil, higher current will also lead to higher ac and smaller motor volume.

Motor speed,

With an increase in motor speed, the required torque to get the same output power reduces and hence the volume and weight of the motor will reduce.

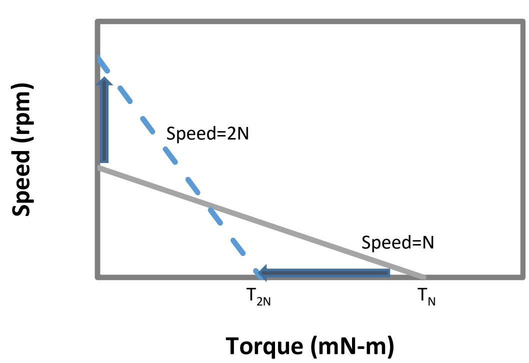
- For example, when a motor's operating speed is doubled to achieve the same output power, the torque required is reduced by 50%.

$\boldsymbol{P_{out1} = T_1\omega_1,\quad P_{out2} = T_2\omega_2}$, **where** $\boldsymbol{\omega = {}^{2\pi N}/_{60}} \quad \boldsymbol{P_{out1} = P_{out2},}$

$$\boldsymbol{\omega_2 = 2\omega_1 \Longrightarrow T_2 = 0.5T_1}$$

$$\boldsymbol{(P_{out}/B_{av}\mathrm{ac}N_s) \propto D^2L}$$

$\boldsymbol{P_{out1} = P_{out2}}$**, and hence, for** $\boldsymbol{N_{s2} = 2N_{s1},\ \Longrightarrow (D^2L)_2 = 0.5(D^2L)_1}$



There are other factors that also play a role in determining the size of the motors like; understanding the duty cycle of the motor (continuous, intermittent, or short time), cooling type as well as the altitude factor. An understanding of above physical factors can help in determining the appropriate motor rating for a specific application.

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