# MIDDLE EAST TECHNICAL UNIVERSITY

# DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

# EE 564: DESIGN OF ELECTRICAL MACHINES

# PROJECT – 2

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## Submission Date:

# Introduction:

In the scope of this project, a PM synchronous machine with a diameter of 240 mm is designed, as a part of design of an integrated modular motor drive system. Considering the previous design with the larger outer diameter, in this iteration, aspect ratio will be increased as the diameter becomes smaller with same output power (and torque). Motor parameters will be analyzed in detail using both analytical calculation techniques and computational tools.

# Winding Design:

Basic properties of the motor may be summarized as follows:

* Number of slots: 24
* Number of poles: 20
* Stator outer diameter: 240 mm
* Stator inner diameter: 150 mm
* Rotor outer diameter: 147 mm
* Rotor inner diameter: 120 mm
* Magnet thickness (included in rotor diameter): 4.5 mm
* Airgap: 1.5 mm

Slot dimensions are given in Figure 1, below:

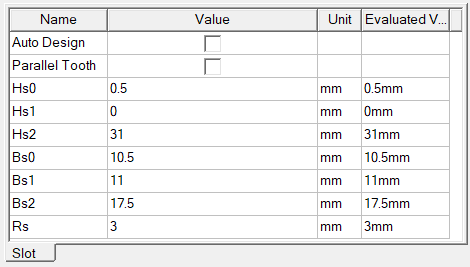


Figure 1: Slot Dimensions

Slot dimension may be approximated to a trapezoid, therefore slot area may be found as:

Lamination type and appearance is provided in Figure 2.

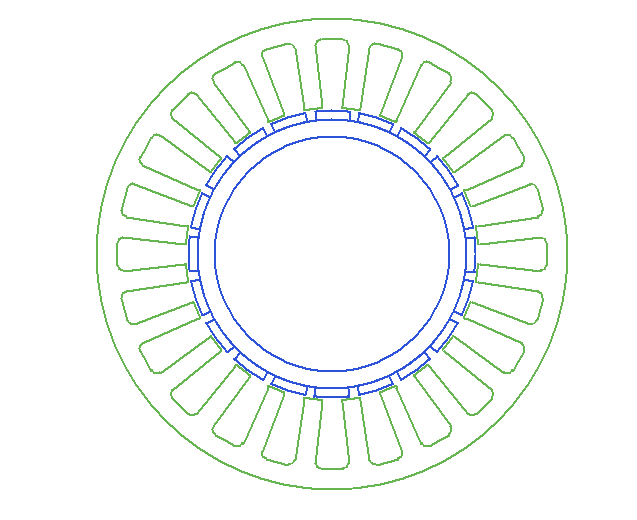


Figure 2: Stator Lamination

## Winding Configuration:

The machine will have a fractional slot, double layer winding.

Winding configuration:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| A- | A | C | C- | B- | B | A | A- | C- | C | B | B- | A- | A | C | C- | B- | B | A | A- | C- | C | B | B- |
| B | A | A- | C- | C | B | B- | A- | A | C | C- | B- | B | A | A- | C- | C | B | B- | A- | A | C | C- | B- |

Connection of the coils is given in Figure 3.

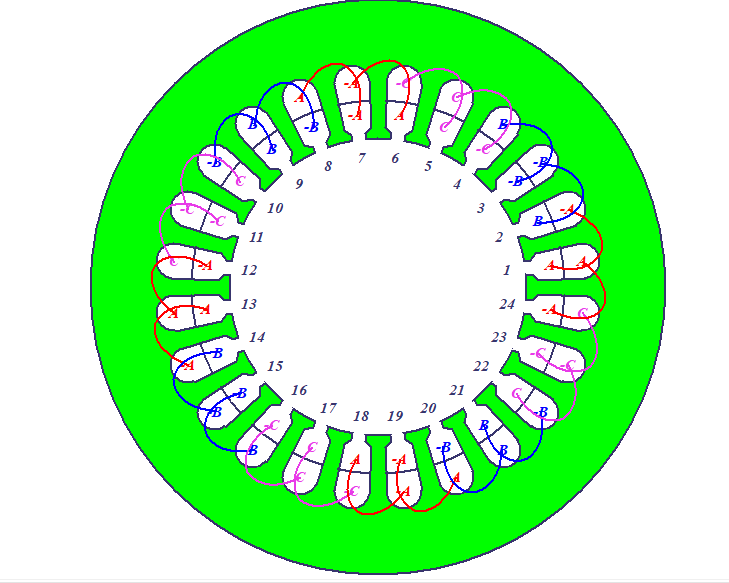


Figure 3: Winding Configuration

For this winding configuration, MMF waveforms for two different excitation cases are given in Figures 4 and 5.

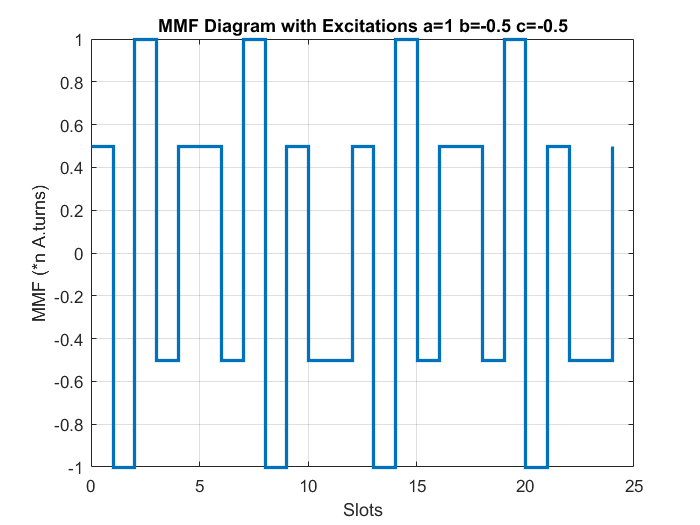


Figure 4: MMF Waveform for Ia=1, Ib=-0.5, Ic=-0.5

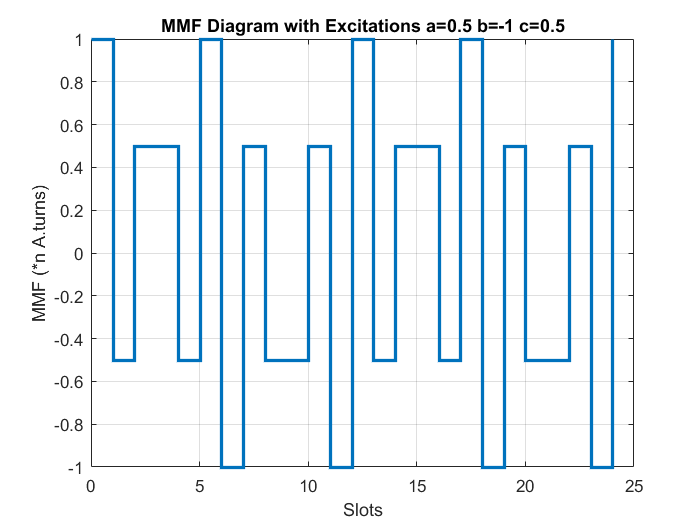


Figure 5: MMF Waveform for Ia=0.5, Ib=-1, Ic=0.5

## Winding Factor:

Distribution factor for nth harmonic order:

Pitch factor for nth harmonic order:

q=2/5, n=1,3,5,7, ,

Table 1: Winding Factors for First 4 Harmonics

|  |  |  |  |
| --- | --- | --- | --- |
| Harmonic Order | k\_d | k\_p | k\_w |
| 1 | 1.294 | 0.966 | 1.250004 |
| 3 | -3.536 | -0.707 | 2.499952 |
| 5 | 4.83 | 0.259 | 1.25097 |
| 7 | -4.83 | 0.259 | -1.25097 |

## Number of Turns: