

# **Tesla Model S Induction Motor**

**RWD 85 Model**

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# Table of Contents

1. Introduction .....	1
2. Main Dimensions of Stator Core .....	2
3. The Stator Winding .....	3

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# Chapter 1. Introduction

The specs of the induction motor are as follows:

```
% Input Parameters of the
% Tesla Model S Induction Motor
power_max = 270;           % [kW] from project2
torque_max = 440;          % [Nm] from project2
speed_max = 225;           % [km/sa] from project2
m = 3;                    % [-] three phases
p1 = 2;                   % [-] pole pair from Hendershot-FIU-Lecture
power Rated = 288 * 0.746 ; % [kW] from Hendershot-FIU-Lecture
tire_diameter = 27.7 * 25.4; % [mm] from
                                % https://tiresize.com/tires/Tesla/Model-S/
                                % https://tiresize.com/tiresizes/245-45R19.htm
                                % [-] 9.73:1 (transmission) from
                                % https://en.wikipedia.org/wiki/Tesla_Model_S
gear = 9.73;              %
speed_rpm_max = (speed_max*10^3/3600)/(tire_diameter*10^-3/2)*(60/2*pi())*gear; %
speed_rpm Rated = 6000;   % [rpm] from Hendershot-FIU-Lecture
                                % approx. knee of the torque-speed curve
f1 = speed_rpm Rated*2*p1/120; % [Hz] frequency of the driver unit
Vd = 400;                 % [V] nominal bus voltage 85kWh from
                                % http://teslatap.com/undocumented/
```

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# Chapter 2. Main Dimensions of Stator Core

$Dis^2 * L$  output constant concept is used to determine parameters.

```
% Based on the The Induction Machine Handbook Chpater 14 & 15
neff = 0.96; % [-] targetted efficiency (IE3)
pwr_factor = 0.88; % [-] typ. power factor for induction motors
% at full load varies between 0.85-0.90
Ke = 0.98 - 0.005*p1; % [-] Ke defined as  $E_1 / V_{ln}$  (eq. 14.8)
% and approx. given as eq. 14.10
Sgap = Ke * powerRated * 10^3 / (neff * pwr_factor); % [VA] (eq. 15.2)
stack_aspect = 1.25; % [-] stack aspect ratio define as
% stack length to pole pitch ratio (eq. 14.19)
% (table 15.1)
Co = 250*10^3; % [J/m^3] extracted from figure 14.14
Dis = ((2*p1*p1*Sgap)/(pi()*stack_aspect*f1*Co))^(1/3); % [m] (eq. 15.1)
pole_pitch = pi()*Dis/(2*p1); % [m] pole pitch (eq. 15.2)
L = stack_aspect * pole_pitch; % [m] stack length (eq. 15.2)
Ftan_max = torque_max / (Dis/2); % [N] tangential force
Sr = pi()*Dis*L; % [m^2] surface area
shear_stress_max = Ftan_max / Sr; % [N/m^2], [Pascal] tangential shear stress
Cmech = power_max / (Dis^2*L*f1/p1); % [kWs/m^3] specific machine constant
max_stator_num = round(pi()*Dis/0.007); % [-] max. stator number from
% ee564_basic_machine_design2, 8/23
min_stator_num = ceil(pi()*Dis/0.045); % [-] min. stator number
Kd = 0.62; % [-] for 2p1 pole number (Table 15.2)
Dout = Dis / Kd; % [m] outer diameter of the stator (eq. 15.4)
g1 = 0.1+0.012*(powerRated*10^3)^(1/3); % [mm] airgap (eq. 15.5)
g2 = 0.18+0.006*(powerRated*10^3)^(0.4); % [mm] airgap from
% ee564_basic_machine_design 16/18

if (g1 > g2)
    g = g1;
else
    g = g2;
end;
g = g * 1.2; % [mm] to add safety factor
```

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## Chapter 3. The Stator Winding

```
% Based on the The Induction Machine Handbook Chpater 14 & 15
Ns = 2*p1*m*4;           % [-] number of stator slots
q = Ns/(2*p1*m);         % [-] slots per pole per phase
pitch_factor = 5/6;      % [-] to minimize 5th and 7th harmonics
pitch_angle = 5/6*180;   % [°] pitch angle
slot_angle_alpha = 180/(Ns/(2*p1)); % [°] slot angle (eq. 15.7)
Kp1 = sind(pitch_angle/2); % [-] fundamental pitch factor (eq. 15.9)
Kd1 = sind(q*slot_angle_alpha/2)/(q*sind(slot_angle_alpha/2));
                        % [-] fundamental distribution factor (eq. 15.8)
Kw1 = Kp1*Kd1;           % [-] fundamental winding factor
Bg = 0.65;               % [Tesla] (e.q. 15.11)
den_shape = 0.729;       % [-] density shape factor fig.14.13, where 1+Kst=1.4
Kf = 1.085;              % [-] form factor fig.14.13
flux_airgap = den_shape*pole_pitch*L*Bg; % [Wb] airgap flux (eq. 5.10)
Vph_rms = 4/pi()*Vd/2*(1/sqrt(2)); % [V] (eq. 8.56 Mohan) rms phase voltage
N_per_ph = Ke*Vph_rms/(4*Kf*Kw1*f1*flux_airgap); % [turns/phase] (eq. 15.12)
a1 = 1;                  % [-] the number of current path in parallel
ns = a1*N_per_ph/(p1*q); % [*] the number of conductors per slot
% to get even number conductors because of double layer winding
if ns<=2
    ns = 2;
else
    ns = ceil(ns);
    if 1 == mod(ns,2)
        ns = ns +1;
    end
end
N_per_ph_req = p1*q*ns; % [turns/phase] required turns/phase
Bg_req = Bg * N_per_ph/N_per_ph_req; % [Tesla] required Bg
Vll_rms = Vph_rms * sqrt(3); % [V] line-line rms voltage
IphRated_rms = powerRated*10^3/(neff*pwr_factor*sqrt(3)*Vll_rms);
                        % [A] rated phase current (eq. 15.16)
Jcos = 5.5;            % [A/mm^2] current density for 2p1=2,4 (eq. 15.17)
Aco = IphRated_rms/(Jcos*a1); % [mm^2] stator wire cross section
dco = sqrt(4*Aco/pi); % [mm] wire gauge diameter (eq. 15.19)
ap = 4;                % [-] number of conductor in parallel
dcop = sqrt(4*Aco/(pi*ap)); % [mm] wire gauge diameter (eq. 15.20)
dcop_sta = 5.189;      % [mm] AWG4 size is chosen by regarding above value
```

The number of stator slots ( $N_s$ ) should be multiple of 12.  
By referring the suggested stator slot pitch for induction machines (7-45mm),  $N_s$  should be between 16-97.  
Let's choose  $N_s$  as 48.  
To reduce harmonic frequency components let's use fractional pitch.  
5/6 fraction is used to reduce 5th and 7th harmonics.  
Note that  
5/6 pitch will  
minimize the 5th harmonic but not eliminate it as will 4/5 pitch  
minimize the 7th harmonic but not eliminate it as will 6/7 pitch