DEMec - Dep. of Mechanical Engineering
SAIC- Automation, Instrumentation and Control Section
Master in Mechanical Engineering

Electromechanical Systems

1st Year– 2nd Semester
2025-2026

Support documents to TP classes

Motor comparison and sizing

Paulo Abreu

2026 Edition

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Comparison and Sizing Electric Motors

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Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Rotor)	Torque/speed curve
Permanent magnet DC (PMDC)	DC	Permanent magnet	Wound	Commutator and Brushes	Direct on-line (DOL) starter or use of PWM driver	Mechanical	
Universal motor (PMDC serial motor)	DC or AC single phase	Wound	Wound	Commutator and Brushes	Direct on-line (DOL) starter or use of PWM driver	Mechanical	
PMDC shunt motor	DC	Wound	Wound	Commutator and Brushes	Direct on-line (DOL) starter or use of PWM driver	Mechanical	

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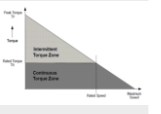
Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
BLDC (brushless)	DC	Wound	Permanent Magnet	Rotor position detection (low resolution)	Driver embedded with the motor, or external driver Use of "Block Commutation"	Electronic (Spatial)	
BLDC (brushless)	DC/AC	Wound	Permanent Magnet		External Driver with FOC - sensorless ("virtual" encoder)	Electronic (Spatial)	
BLDC (brushless)	DC/AC	Wound	Permanent Magnet	Rotor position detection (high resolution)	External Driver with FOC and real encoder/resolver	Electronic (Spatial)	

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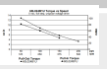
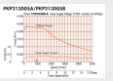
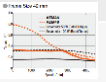
Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
Permanent magnet (PM) stepper	DC	Wound	Permanent Magnet		Driver	Electronic (Temporal)	
Variable Reluctance (VR) stepper	DC	Wound	Reluctance		Driver	Electronic (Temporal)	
Hybrid (HB) stepper	DC	Wound (2- phase; 4, 5, 6 or 8 wires) Wound (5- phases, 5 wires)	Permanent Magnet + Reluctance		Driver (unipolar or bipolar driver, Driver for 5-phase motor)	Electronic (Temporal)	
Hybrid (HB) stepper	DC/AC	Wound	Permanent Magnet + Reluctance	Rotor position detection (high resolution)	Driver with FOC	Electronic (Spatial)	

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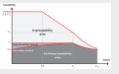
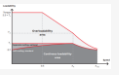
Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
Induction	AC single phase	Wound	Squirrel cage	Capacitor for starting	DOL	From the grid	
Single Phase Synchronous motor	AC single phase	Wound	Permanent Magnet	Mechanical device for imposing rotation direction	DOL	From the grid	
Permanent Magnet Synchronous motor (PMSM)	AC three phase	Wound	Permanent Magnet	Without or with Rotor position detection (high resolution)	VFD with V/f control or FOC (sensorless / with sensor)	Electronic	
Synchronous reluctance motor - SynRM	AC three phase	Wound	Reluctance	Without or with Rotor position detection (high resolution)	VFD with FOC	Electronic	

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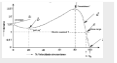
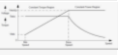
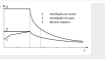
Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
Induction Motor (IM) (asynchronous)	AC three phase	Wound	Squirrel cage		DOL	From the grid	
Induction Motor (IM) (asynchronous)	AC three phase	Wound	Squirrel cage		VFD with V/f control	Electronic	
Induction Motor (IM) (asynchronous)	AC three phase	Wound	Squirrel cage		VFD with FOC sensorless	Electronic (Spatial)	
Induction Motor (IM) (asynchronous)	AC three phase	Wound	Squirrel cage	Rotor position detection (high resolution: encoder or resolver)	VFD with FOC	Electronic (Spatial)	

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Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
LSPM Motor	AC three phase	Wound	Squirrel cage + Permanent Magnet		DOL or VFD	From grid/ Electronic	
Internal Permanent Magnet Synchronous Reluctance Motor (IPM-SynRM)	AC three phase	Wound	Reluctance + Permanent Magnet	-- / encoder-resolver	VFD with FOC (sensorless /with sensor)	Electronic	
Axial flux motor (AFM)	AC three phase	Wound	Permanent Magnet		VFD with FOC (sensorless)	Electronic	

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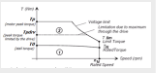
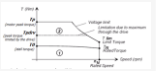
Motor Comparison

Motor Designation	Power source	Stator	Rotor	Other key components	Control	Type of commutation (in Stator)	Torque/speed curve
Axial Flux Motor (AFM)	Driver dependent (AC or DC)	Wound	Permanent magnet	Rotor position detection (high resolution: encoder or resolver)	VFD with FOC	Electronic	
Servomotor (PMSM) (Permanent Magnet Synchronous Motor)	Driver dependent (AC or DC)	Wound	Permanent magnet	Rotor position detection (high resolution: encoder or resolver)	Driver with FOC	Electronic	

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Motor Comparison

https://www.nidec.com/en/technology/capability/brushless/

	AC motor			Universal motor	Brush DC motors	Brushless DC motor	Stepping motor	Servo motor	
	Single-phase	Three-phase (Induction)	Three-phase (Sync)					AC servo	DC (brushed) servo
Power type	AC			AC/DC	DC	DC (including driver)/Driver	Drivers	Drivers	Drivers
Efficiency	40-60%	60-70%	70-80 %	50-60%	60-80%	80 %	60-70%	50-80%	60-80%
Size (same output)	Large	Intermediate or large		Large	Small	Small	Intermediate	Small or intermediate	Small
Noise	Small			Large	Large	Small	Intermediate	Small	Large
Speed range	Narrow	Wide		Intermediate	Wide	Wide	Wide	Intermediate	Narrow
Response	Slow			Slow	Intermediate	Intermediate	Intermediate	Fast	
Service life	Long			Short	Short	Long	Long	Long	Short
Price	Low		Intermediate	Low	Low	Intermediate or high	Intermediate	High	
Applications	Washing machines Air blowers Vacuum cleaners Pumps	Cranes Conveyors Air conditioners Industrial machinery	Compressors Dishwashers Washing machines	Vacuum cleaners Electric tools Juicers	Electric toys Electric tools Automobile electric components Small home appliances	Air conditioners Dishwashers Washing machines Small home appliances	Robots Small home appliances Air-conditioning equipment	Conveyors Robots Machine tools	Printers Plotters Working machines
Judgment	Cost focused	Versatility focused Cost focused		Cost focused	Cost focused	Efficiency focused Versatility focused	Versatility focused	Performance focused	

Key Considerations in Motor-Driver Selection

Selecting an electric-driven system (Motor + Driver) is a **multi-dimensional** engineering challenge and an **iterative process**. The process must integrate:

- Phase I: Mechanical Load and Operational Analysis
- Phase II: Core Motor Dynamics
- Phase III: Application-Specific Selection
- Phase IV: Validation and Calculations

Phase I: Mechanical Load and Operational Analysis

Before selecting hardware, define the mechanical, control, and environmental boundary conditions.

- **Mechanical** Load Profile
  - Identify static vs. dynamic torque, required power, and operating speed
- **Transmission Impact**
  - Evaluate gear ratios and gear efficiency and how they reflect load inertia back to the motor
- **Operational Constraints**
  - Define physical size/weight limits, required IP ratings for environmental durability (dust, water, radiation), and electrical installation availability, and cost constraints
- **Control Requirements**
  - Assess whether the application requires an open-loop (simplicity) or closed-loop (high-precision/high-speed) command strategy, and select either an electromechanical or programmable control solution

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Phase II: Core Motor Dynamics

Focus on the physics of the motor-to-load relationship.

- **Inertia Matching**
  - Proper inertia matching is essential for system performance. A high load-to-motor inertia ratio (J_{load}/J_{motor}) leads to longer acceleration and deceleration times, which degrades dynamic response. Here, J_{load} denotes the load inertia reflected to the motor shaft
- **Torque Margins**
  - Always select a motor that provides more torque than required to account for wear and lubrication issues. Typical margin values of 50% for stepper motors and 20% for servos
- **Torque/Speed Characteristics**
  - Ensure the motor/driver combo meets the specific torque requirements at the speeds required by the application

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Phase III: Application-Specific Selection

Select the motor type and driver based on the specific load behavior

- Load Characteristic Categories

Load Type	Description	Examples
Constant Torque	Torque remains stable at nominal levels	Conveyors, positive displacement pumps
Variable Torque	Torque varies (often squared) with speed	Fans, centrifugal pumps, agitators
Constant Power	Torque is inversely proportional to speed	CNC spindles, centrifuges, extruders
High Starting Torque	Needs massive initial force under load	Compressors
Regenerative	Load feeds energy back to the motor	Elevators, downhill conveyors

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Phase IV: Validation & Calculations

For dynamic sequences, finalize selection by calculating effective values for torque and speed, using the following formulas

$$T_{effective} = \sqrt{\frac{1}{t_{cycle}} \cdot (T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + \cdots + T_n^2 \cdot t_n)} \qquad n_{effective} = \sqrt[1.5]{\frac{1}{t_{cycle}} \cdot (n_1^{1.5} \cdot t_1 + n_2^{1.5} \cdot t_2 + \cdots + n_n^{1.5} \cdot t_n)}$$

- Use effective torque and speed for starting choice for motor/driver;
- Then verify that maximum values are possible to achieve by the selected motor/driver
- Verify the load-to-motor inertia ratio (J_{load}/J_{motor} < recommended value)

Many suppliers provide online software for sizing motor and driver

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Phase IV: Validation & Calculations

Specific Motor Checks **in asynchronous induction motors**

- Vertical movement
  - calculate required power, including transmission system, and consider only required static power (not including motor)
  - check if the selected motor has acceleration torque (consider load and motor!)
  - check acceleration time, considering the motor starting torque
- Horizontal movement
  - calculate required power, including transmission system, and consider static and dynamic required power
  - check if the selected motor has acceleration torque
  - check acceleration time, considering the motor starting torque

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Phase IV: Validation & Calculations

Specific Motor Checks in **asynchronous induction motors, powered by an VFD**

- Pay attention to the supply voltage, frequency, and motor coils configuration (delta/star)
- Verify available nominal and maximum torque at the required operating frequency

$$T_N^{f2} = T_N^{fbase}\left(\frac{f_{base}}{f_2}\right) \;\therefore\; T_{máx}^{f2} = T_{máx}^{fbase}\left(\frac{f_{base}}{f_2}\right)^2 \;:\; T_L^{f2} < T_N^{f2} \quad e \quad T_L^{f2} < T_{máx}^{fbase}$$

- Check available torque by the power of the VFD at the maximum desired operating frequency
- Select the type of operation for the VFD (V/f, vector control (FOC) – open loop or closed loop)

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Phase IV: Validation & Calculations

Specific Motor Checks in **Servomotors:**

- Use effective torque and speed for starting choice for motor/driver
- Then verify that maximum values are possible to achieve by the selected motor/driver
- Check motor stall torque and driver-provided torque limits
- Check driver supply voltage influence on motor performance
- **Check the** load-to-motor inertia ratio (J_{load}/J_{motor} < recommended value)

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Phase IV: Validation & Calculations
Load-to-motor inertia ratio

The recommended load-to-motor inertia ratio (J_{load}/J_{motor}) depends on type of motor, control drive, and required dynamics

Typical values

- **Direct-Drive Servos** (High-Performance)
  - Recommended Ratio: 1:1
  - This is the gold standard to ensure the highest possible bandwidth and maximum control stiffness

- **Standard Servomotors**
  - Recommended Ratio: up to 5:1 (J_{load}/J_{motor} < 5)
  - Modern digital servo drives use sophisticated PID algorithms that can handle higher ratios. In some cases it is acceptable a ratio of 10:1. However, as the ratio increases, the "tuning" becomes more difficult and the system dynamic response worsens

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Phase IV: Validation & Calculations
Load-to-motor inertia ratio

Typical values

- BLDC motors
  - Recommended Ratio: up to 10:1 (J_{load}/J_{motor} <10)

- Stepper Motors (Open-Loop)
  - Recommended Ratio for smaller motors: up to 5:1 (J_{load}/J_{motor} <5)
  - Recommended Ratio for larger motors: up to 5:1 (J_{load}/J_{motor} <10)
  - As there is no feedback to correct for position errors, high inertia ratios can cause the motor to "lose steps" during deceleration or due to resonance. Use also high torque margin (T_{motor} = 1.5 up to 2 T_{load})

- Stepper Motors (Closed-Loop)
  - Recommended Ratio: up to 30:1 (J_{load}/J_{motor} <30)

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Phase IV: Validation & Calculations
Load-to-motor inertia ratio

Typical values

- Large Induction Motors (VFD Controlled)
  - Acceptable: up to 50:1
  - Because these systems are often used for "velocity control" (fans, pumps, conveyors) rather than "position control," they can tolerate significantly higher inertia ratios. The primary constraint here is the Start-up Time (t_a) and the thermal capacity of the motor during acceleration

Note: always prioritize the specific motor manufacturer's technical specifications over general rules of thumb

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Load-to-motor inertia ratio

Motor Type	Control Drive	Recommended * J_{load}/J_{motor}	Required Torque Margin *
Direct Drive	High-Precision	1:1	10 % - 20 %
Servo	Closed-Loop	Up to 5:1	20 %
BLDC	Closed-Loop	Up to 10:1	20 %
Stepper	Open-Loop	Up to 5:1	> 50 %
Stepper	Closed-Loop	Up to 30:1	> 50 %
Induction	VFD (V/f)	Up to 50:1	10 % - 15 %

*** See always recommendations from motor manufacturer's technical specifications**

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Formulas in Motor Sizing

General considerations

Rotational Motion
Translational Motion

$$P = T \cdot \omega = J \cdot \alpha \cdot \omega$$
$$P = F \cdot v$$

$$\mathbf{T = J \cdot \alpha}$$
$$\boldsymbol{\omega = \frac{n \cdot 2\pi}{60}}$$

$$\eta = \frac{P_{out}}{P_{in}}$$
$$\boldsymbol{i = \frac{\omega_{in}}{\omega_{out}} = \frac{n_{in}}{n_{out}} = \frac{a_{in}}{a_{out}}}$$

Rotational Motion

$$J_{massJ}^{motor} = \frac{J_{massJ}^{load}}{\eta}\left(\frac{n_{massJ}^{load}}{n_{motor}}\right)^2 = \frac{J_{massJ}^{load}}{\eta \cdot i^2}$$

Translational Motion

$$J_{massM}^{motor} = \frac{J_{massM}^{load}}{\eta}\left(\frac{n_{massM}^{load}}{n_{motor}}\right)^2 = \frac{m}{\eta} * \left(\frac{v_{massM}^{load}}{\omega_{motor}}\right)^2$$

$P = Power\ [W] = [Nm/s]$
$T = Torque\ [Nm]$

$\omega = angular\ velocity\ [rad/s]$
$n = angular\ velocity\ [rpm]$
$\alpha = angular\ acceleration\ [rad/s^2]$

$\eta = efficiency\ of\ transmission$

$i = transmission\ ratio$

$v = linear\ velocity\ [m/s]$

$a = linear\ acceleration\ [m/s^2]$
$F = force\ [N]$
$m = mass\ [kg]$

$J = moment\ of\ inertia\ [kgm^2]$

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Formulas in motor sizing
Static and Dynamic Power

General considerations

Power due to load, and seen by motor

$$P_{total} = P_{static} + P_{dynamic} \quad [W]$$

P_{static} : Rotational Motion

$$P_{static} = \frac{T_{load}^{load} \cdot \omega_{load}^{load}}{\eta}$$

Translational Motion

$$P_{static} = \frac{F_{load}^{load} \cdot v_{load}^{load}}{\eta}$$

$P_{dynamic}$: Rotational Motion

$$P_{dynamic} = P_{acceleration_Jmotor} + P_{acceleration_massJ}$$
$$= J_{motor} \cdot \alpha_{motor} \cdot \omega_{motor} + J_{massJ}^{motor} \cdot \alpha_{motor} \cdot \omega_{motor}$$
$$= J_{motor} \cdot \alpha_{motor} \cdot \omega_{motor} + \frac{J_{massJ}^{load} \cdot \alpha_{massJ}^{load} \cdot \omega_{massJ}^{load}}{\eta}$$

Translational Motion

$$P_{dynamic} = P_{acceleration_Jmotor} + P_{acceleration_massM}$$
$$= J_{motor} \cdot \alpha_{motor} \cdot \omega_{motor} + \frac{m_{massM}^{load} \cdot a_{massM}^{load} \cdot v_{massM}^{load}}{\eta}$$

efficiency of the mechanical transmission system

$\sum$ moments of inertia referred to the motor shaft

$\sum$ moments of inertia referred to the load axis

rotor moment of inertia can be significant!

$\sum$ of all masses referred to the body, on the load side

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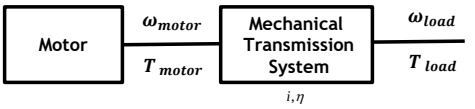
Formulas in motor sizing
Effect of Transmission System on Torque

Reflecting Load Torque to the Motor Shaft: Influence of Reduction Ratios and Transmission Efficiency

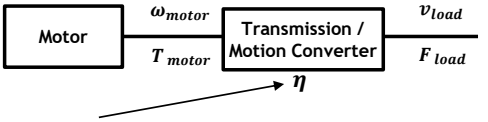
- Rotational Motion



$$T_{motor} = \frac{T_{load}}{\eta} \cdot \frac{\omega_{load}}{\omega_{motor}}$$

$$T_{motor} = \frac{T_{load}}{\eta} \cdot \frac{1}{i} \quad \text{with } i = \frac{\omega_{motor}}{\omega_{load}}$$

- Translational Motion

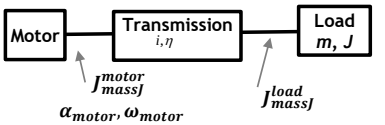


$$T_{motor} = \frac{F_{load}}{\eta} \cdot \frac{v_{load}}{\omega_{motor}}$$

Impact of Transmission Efficiency on System Sizing

Formulas in motor sizing

Effect of using a transmission system on dynamic power



- Rotational motion

$$P_{accelaration_massJ}^{motor} = J_{massJ}^{motor} \cdot \alpha_{motor} \cdot \omega_{motor}$$

$$= \frac{J_{massJ}^{load}}{\eta \cdot i^2} \cdot \alpha_{motor} \cdot \omega_{motor}$$

Mechanical Transmission System Efficiency

Transmission Ratio

$$i = \frac{n_{motor}}{n_{massM}^{load}}$$

$\alpha_{motor}, \omega_{motor}$

Transmission Ratio Increases

Dynamic Power Decreases

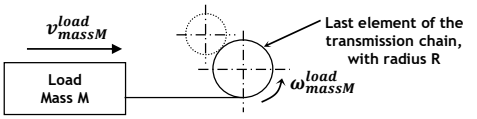
- Translational motion

$$P_{accelaration_massM}^{motor} = \frac{m \cdot a_{massM}^{load} \cdot v_{massM}^{load}}{\eta} = \frac{J_{massM}^{load} \cdot a_{massM}^{load} \cdot \omega_{massM}^{load}}{\eta}$$

$$J_{massM}^{load} = mR^2$$

$$\alpha_{massM}^{load} = \frac{a_{massM}^{load}}{R}$$

$$\omega_{massM}^{load} = \frac{v_{massM}^{load}}{R}$$



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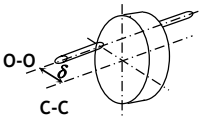
Formulas in motor sizing

Moment of Inertia: $J \ [Kg \cdot m^2]$

$$J = \sum r^2 \Delta m = \int r^2 dm$$



Steiner´s Theorem

$$J_O = J_C + m\delta^2$$

Moment of Inertia of body with mass *m* referred to the motor axis

- Rotational motion

$$J_{massJ}^{motor} = \frac{J_{massJ}^{body}}{\eta}\left(\frac{n_{massJ}^{body}}{n_{motor}}\right)^2 = \frac{J_{massJ}^{body}}{\eta \cdot i^2}$$

- Translational motion

$$J_{massM}^{motor} = \frac{m}{\eta}\left(\frac{v_{massM}^{body}}{\omega_{motor}}\right)^2$$

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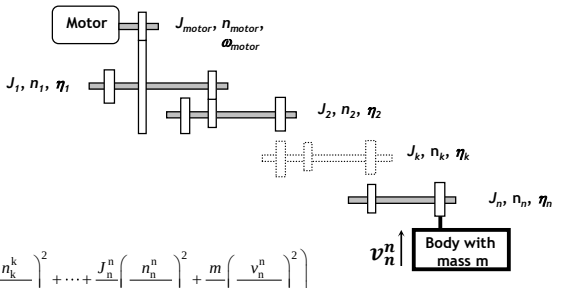
Formulas in motor sizing

Moment of inertia: $J \ [Kg \cdot m^2]$



$$J_{\text{total}} = \left(J_{motor} + \frac{J_1^1}{\eta_1}\left(\frac{n_1^1}{n_{motor}}\right)^2 + \frac{J_2^2}{\eta_2}\left(\frac{n_2^2}{n_{motor}}\right)^2 + \cdots + \frac{J_k^k}{\eta_k}\left(\frac{n_k^k}{n_{motor}}\right)^2 + \cdots + \frac{J_n^n}{\eta_n}\left(\frac{n_n^n}{n_{motor}}\right)^2 + \frac{m}{\eta_n}\left(\frac{v_n^n}{\omega_{motor}}\right)^2 \right)$$

Where η_k represents the total efficiency of the transmission chain from the motor shaft to the k axis

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Formulas in motor sizing

Total motor torque

- Rotational motion

$$T_{total} = \frac{P_{total}}{\omega_{motor}}$$
$$= T_{acc.Jmotor} + T_{acc.massJ} + T_{staticLoad}$$
$$= J_{motor}\alpha_{motor} + J_{massJ}\alpha_{motor} + T_{staticLoad}$$
$$= J_{motor}\alpha_{motor} + \left(\frac{J_{massJ}^{load}\cdot\alpha_{massJ}^{load}}{\eta} * \frac{\omega_{massJ}^{load}}{\omega_{motor}}\right) + \left(\frac{T_{load}^{load}}{\eta} * \frac{\omega_{load}^{load}}{\omega_{motor}}\right)$$

- Translational motion

$$T_{total} = \frac{P_{total}}{\omega_{motor}}$$
$$= T_{acc.Jmotor} + T_{acc.massM} + T_{staticLoad}$$
$$= T_{acc.Jmotor} + J_{massM}\alpha_{motor} + T_{staticLoad}$$
$$= J_{motor}\alpha_{motor} + \left(\frac{m * \alpha_{massM}^{load}}{\eta} * \frac{v_{massM}^{load}}{\omega_{motor}}\right) + \left(\frac{F_{load}^{load}}{\eta} * \frac{v_{massM}^{load}}{\omega_{motor}}\right)$$

With J_{massJ} and J_{massJ}^{load} representing the sum of all moments of inertia external to the motor referred to the motor axis, and to the axis of load application, respectively

With m representing the sum of all the masses referred to in the body where the load F is applied

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Formulas in motor sizing
Start-up Time for Rotational Motion

Start-up time (t_a)

$$\sum T = J\alpha$$

- Rotational Motion

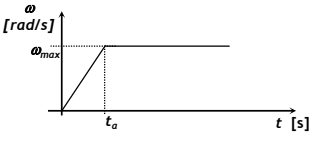
(The torque load opposes the motion)

$$T_{start} - T_{load} = J_{load} \cdot \alpha_{motor}$$

$$\alpha_{motor} = \frac{\omega_{motor} - 0}{t_a}$$

$$t_a = \frac{J_{motor} + J_{massJ}}{T_{start} - T_{load}} \cdot \omega_{motor}$$

$$t_a = \frac{J_{motor} + \frac{J_{massJ}^{load}}{\eta}\left(\frac{n_{massJ}^{load}}{n_{motor}}\right)^2}{T_{start} - T_{load}} \cdot \omega_{motor} = \frac{J_{motor} + \frac{J_{massJ}^{load}}{\eta \cdot i^2}}{T_{start} - T_{load}} \cdot \omega_{motor}$$



Velocity profile at start-up

T_{start} is the motor available startup torque

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Formulas in motor sizing
Start-up Time for Horizontal Translation Motion or Vertical Upwards

Start-up time (t_a)

- Horizontal translation motion or vertical upwards
  (The torque load opposes motion)

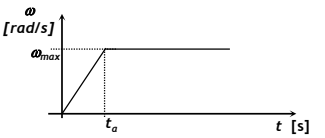
$$\sum T = J\alpha$$

$$T_{start} - T_{load} = J_{total_load} \cdot \alpha_{motor}$$

$$\alpha_{motor} = \frac{\omega_{motor} - 0}{t_a}$$

$$t_a = \frac{J_{motor} + J_{massJ}}{T_{start} - T_{load}} \cdot \omega_{motor}$$

$$t_a = \frac{J_{motor} + \frac{m}{\eta}\left(\frac{v_{massM}^{load}}{\omega_{motor}}\right)^2}{T_{start} - T_{load}} \cdot \omega_{motor}$$



Velocity profile at start-up

T_{start} is the motor available startup torque

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Formulas in motor sizing
Start-up Time for Vertical Motion Downwards

Start-up time (t_a)

$$\sum T = J\alpha$$

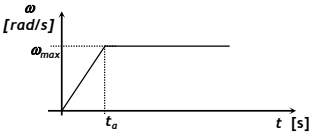
- Translational vertical motion, downwards
  (The torque load acts in the same way as the motion)

$$T_{start} + T_{load}^{motor} = J_{total_load}^{motor} \cdot \alpha_{motor}$$

$$\alpha_{motor} = \frac{\omega_{motor} - 0}{t_a}$$

$$t_a = \frac{J_{motor} + J_{massJ}^{motor}}{T_{start} + T_{load}^{motor}} \cdot \omega_{motor}$$

$$t_a = \frac{J_{motor} + \frac{m}{\eta}\left(\frac{v_{massM}^{load}}{\omega_{motor}}\right)^2}{T_{start} + T_{static} \times \eta^2} \cdot \omega_{motor}$$



Velocity profile at start-up

T_{start} is the motor available startup torque

Note that

$$T_{load}^{motor} = T_{load}^{load} \times \eta^* \times i^* = \frac{T_{load}^{load} \times \omega_{massM}^{load}}{\eta} \times \frac{1}{\omega_{motor}} \eta^2$$

$$= \frac{P_{static}}{\omega_{motor}} \eta^2 = T_{static} \times \eta^2$$

where the ratio $i^* = 1 / i = \omega_{load} / \omega_{motor}$

$\eta^* = \eta$ = efficiency of transmission

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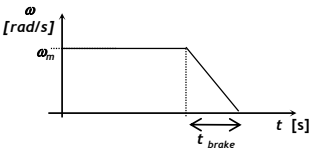
Formulas in motor sizing
Braking time for Rotational Motion

Braking time (t_{brake})

$$\sum T = J\alpha$$

- Rotational motion
  (The torque load opposes the motion)



Velocity profile at braking

$$t_{brake} = \frac{J_{motor} + J_{massJ}^{load} \cdot \left(\frac{\omega_{massJ}^{load}}{\omega_{motor}}\right)^2 \cdot \eta}{T_{braking} + T_{static} \cdot \eta^2} \cdot \omega_{motor}$$

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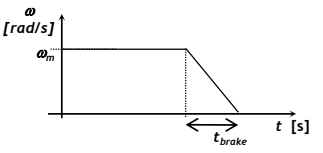
Formulas in Motor Sizing
Braking time for Translational Horizontal Motion or Vertical Upwards

Braking time (t_{brake})

$$\sum T = J\alpha$$

- Translational horizontal motion or vertical upwards
  (The torque load opposes the motion)



Velocity profile at braking

$$t_{brake} = \frac{J_{motor} + m \cdot \left(\frac{v_{massM}^{load}}{\omega_{motor}}\right)^2 \cdot \eta}{T_{braking} + T_{static} \cdot \eta^2} \cdot \omega_{motor}$$

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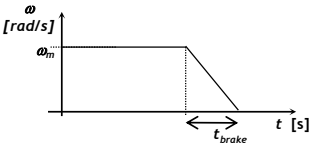
Formulas in Motor Sizing
Braking time for Translational Vertical Downwards

Braking time (t_{brake})

$$\sum T = J\alpha$$

- Translational vertical motion, downwards

  (The torque load acts in the same way as motion)



Velocity profile at braking

$$t_{brake} = \frac{J_{motor} + m \cdot \left(\frac{v_{massM}^{load}}{\omega_{motor}}\right)^2 \cdot \eta}{T_{braking} - T_{static} \cdot \eta^2} \cdot \omega_{motor}$$

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Online tools for sizing motors and drivers

- **Faulhaber** Drive Calculator (**DC motors**, **BLDC**, **stepper**)
  https://www.faulhaber.com/en/drive-calculator/fdc
- **Orientalmotor** Oriental (**Stepper, DC, BLDC**)
  https://www.orientalmotor.com/motor-sizing/index.html
- **JVL** motors (**integrated servo motors and stepper motors**) https://motorsizer.azurewebsites.net/
- **SEW** (**asynchronous, servomotors, and drives**)
  https://www.sew-eurodrive.de/os/ds/?country=DE&language=en_US
- **ABB** (**asynchronous, servomotors, drives**)
  https://www.drivesize.abb-drives.com/
- **DEMAG** (cranes, hoists, asynchronous, and drives)
  http://www.demag-designer.com/
- **Lenz** (**asynchronous and servo motors, and drives**)
  https://systemdesigner.lenze.com
- **Danfoss**
  https://select.mydrive.danfoss.com/

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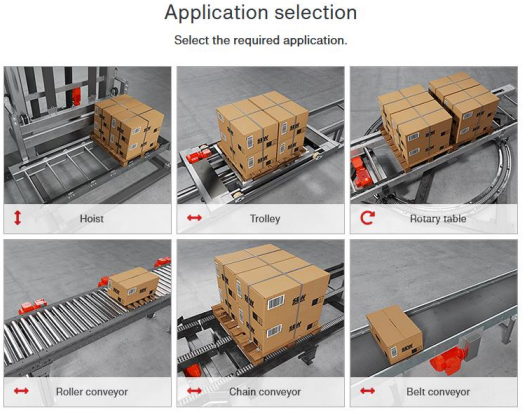
SEW Drive Selection



Selection parameters:

- Type of application
- Inverter operation, or mains operation, or DC 48 V operation
- Gear unit proprieties
- Brake
- Country of use (voltage/freq.)

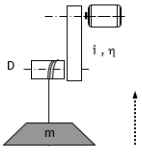
https://www.seweurodrive.com/os/ds/driveselection/applicationselection

SEW Drive Selection: hoist with DOL

Need to specify:

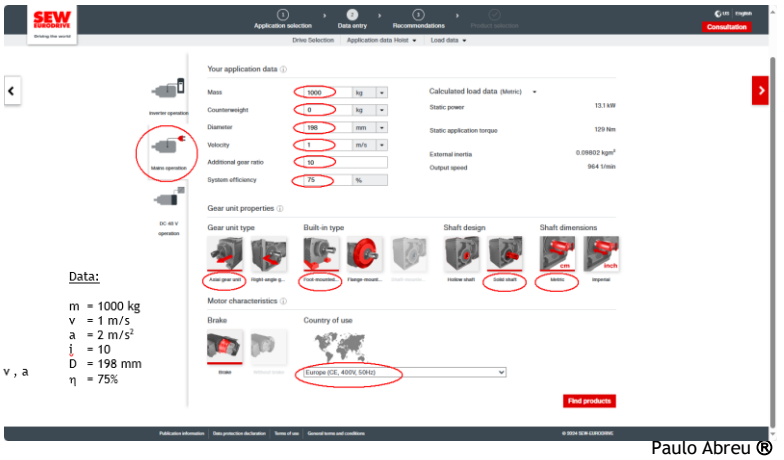
- Mass
- Counter weight
- Diameter
- Velocity
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use



Data:

m = 1000 kg
v = 1 m/s
a = 2 m/s²
i = 10
D = 198 mm
η = 75%



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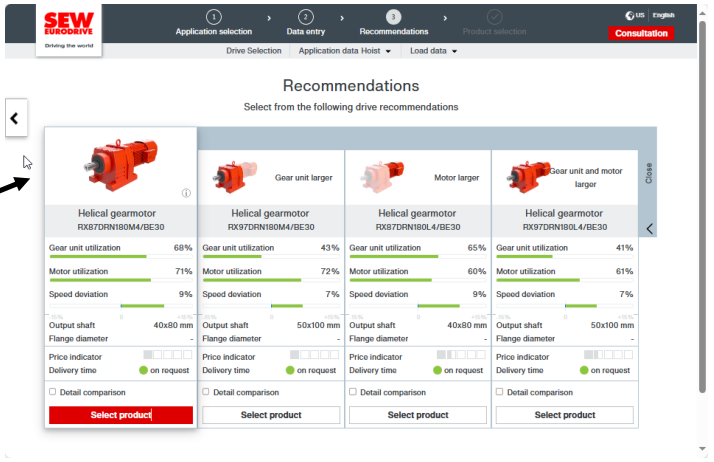
SEW Drive Selection: hoist with DOL

Helical gearmotor RX87DRN180M4/BE30

Catalog designation	RX87DRN180M4/BE30
Rated motor speed	1478 1/min
Output speed	1060 1/min
Overall gear ratio	1.39
Output torque	166 Nm
Maximum permitted output torque	290 Nm
Service factor SEW	1.75
Permitted output overhung load w...	3660 N
Motor power	18.5 kW
Braking torque	300 Nm



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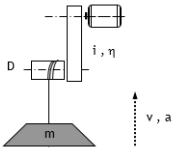
SEW Drive Selection: hoist with VFD

Need to specify:

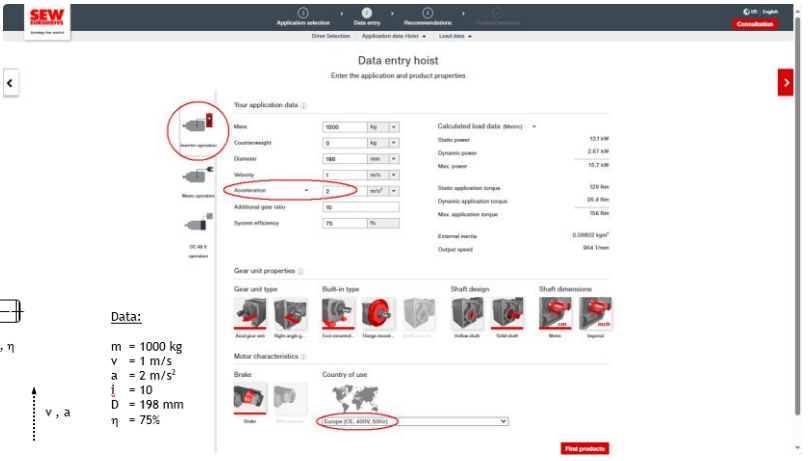
- Mass
- Counter weight
- Diameter
- Velocity
- Acceleration
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use



Data:

m = 1000 kg
v = 1 m/s
a = 2 m/s²
i = 10
D = 198 mm
η = 75%



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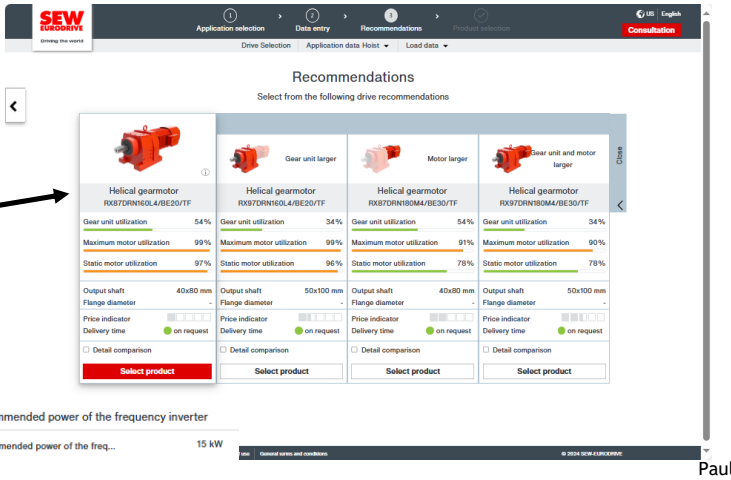
SEW Drive Selection: hoist with VFD



Helical gearmotor RX87DRN160L4/BE20/TF

Catalog designation	RX87DRN160L4/BE2...
Rated motor speed	1474 1/min
Output speed	1060 1/min
Overall gear ratio	1.39
Output torque	135 Nm
Maximum permitted output torque	290 Nm
Service factor SEW	2.1
Permitted output overhung load w...	3830 N
Motor power	15 kW
Braking torque	200 Nm

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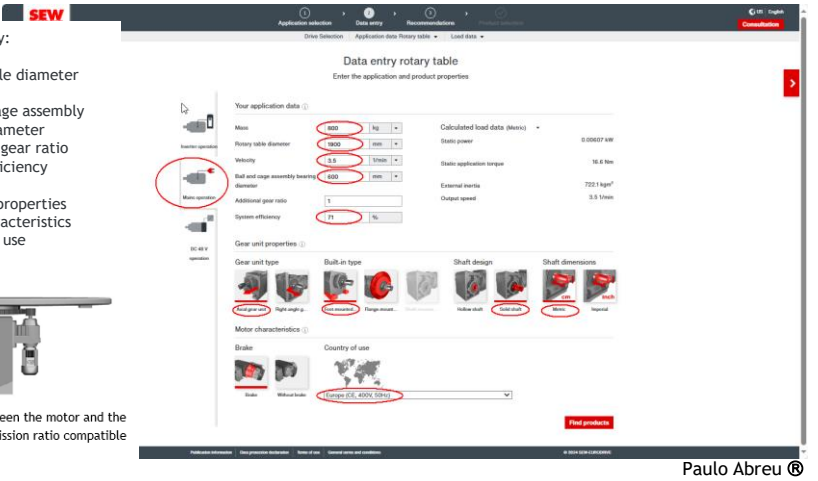
SEW Drive Selection: rotary table with DOL

Need to specify:
- Mass
- Rotary table diameter
- Velocity
- Ball and cage assembly bearing diameter
- Additional gear ratio
- System efficiency
- Gear unit properties
- Motor characteristics
- Country of use

- $m_{moving\ parts} = 550\ Kg$
- $m_{table\ moving\ mass} = 250\ Kg$
- $\Phi_{table} = 1{,}9\ \mathrm{m}$
- $\Phi_{support\ bearings\ position} = 0{,}6\ \mathrm{m}$
- $\mu_{support\ bearings\ friction} = 0{,}015$
- $J^{table\ axis}_{total\ moving\ masses} = 650\ Kgm^2$
- $n_{table} = 3.5\ rpm$
- $t_{acceleration} = 0.5\ s$
- $\eta_{global} = 71\ \%$, of the mechanical transmission system between the motor and the table (includes a gear box, pinion and sprocket, and a transmission ratio compatible with 4-pole motors per phase).



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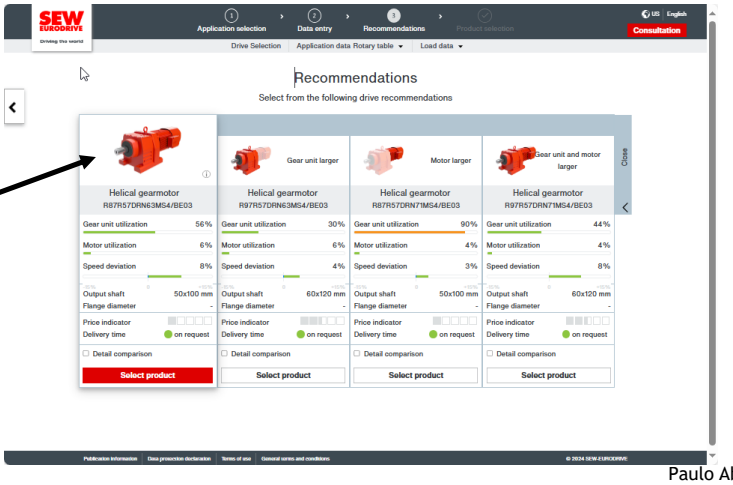
SEW Drive Selection: rotary table with DOL

Helical gearmotor R87R57DRN63MS4/BE03

Catalog designation	R87R57DRN63MS4/...
Rated motor speed	1380 1/min
Output speed	3.8 1/min
Overall gear ratio	361
Output torque	235 Nm
Maximum permitted output torque	1550 Nm
Service factor SEW	6.5
Permitted output overhung load w...	20000 N
Motor power	0.12 kW
Braking torque	1.7 Nm



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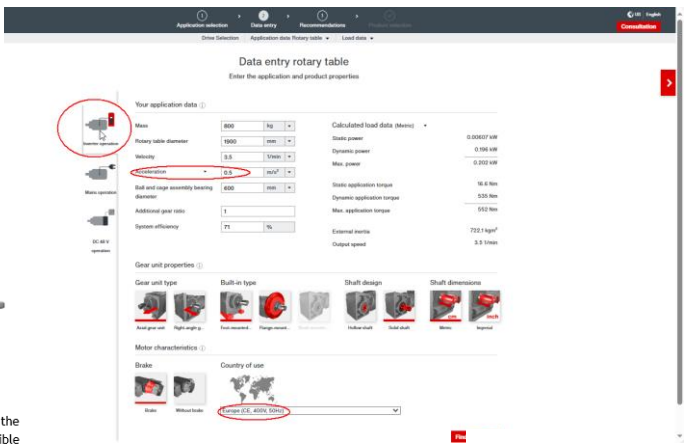
SEW Drive Selection: rotary table with VFD

Need to specify:

- Mass
- Rotary table diameter
- Velocity
- Acceleration
- Ball and cage assembly bearing diameter
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use

- $m_{moving\ parts} = 550\ Kg$
- $m_{table\ moving\ mass} = 250\ Kg$
- $\Phi_{table} = 1{,}9\ \mathrm{m}$
- $\Phi_{support\ bearings\ position} = 0{,}6\ \mathrm{m}$
- $\mu_{support\ bearings\ friction} = 0{,}015$
- $J^{table\ axis}_{total\ moving\ masses} = 650\ Kgm^2$
- $n_{table} = 3{,}5\ rpm$
- $t_{acceleration} = 0{,}5\ s$
- $\eta_{global} = 71\ \%$, of the mechanical transmission system between the motor and the table (includes a gear box, pinion and sprocket, and a transmission ratio compatible with 4-pole motors per phase).



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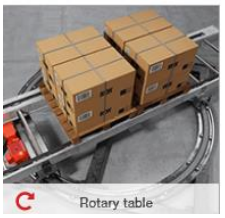
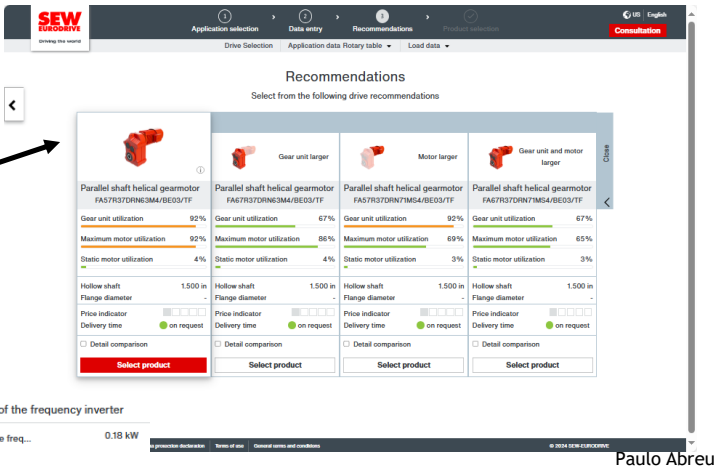
SEW Drive Selection: rotary table with VFD





Parallel shaft helical gearmotor FA57R37DRN63M4/BE03/TF

Catalog designation	FA57R37DRN63M4/...
Rated motor speed	1375 1/min
Output speed	3.6 1/min
Overall gear ratio	386
Output torque	405 Nm
Maximum permitted output torque	600 Nm
Service factor SEW	1.55
Permitted output overhung load w...	11500 N
Motor power	0.18 kW
Braking torque	2.7 Nm

Recommended power of the frequency inverter

Recommended power of the freq...	0.18 kW

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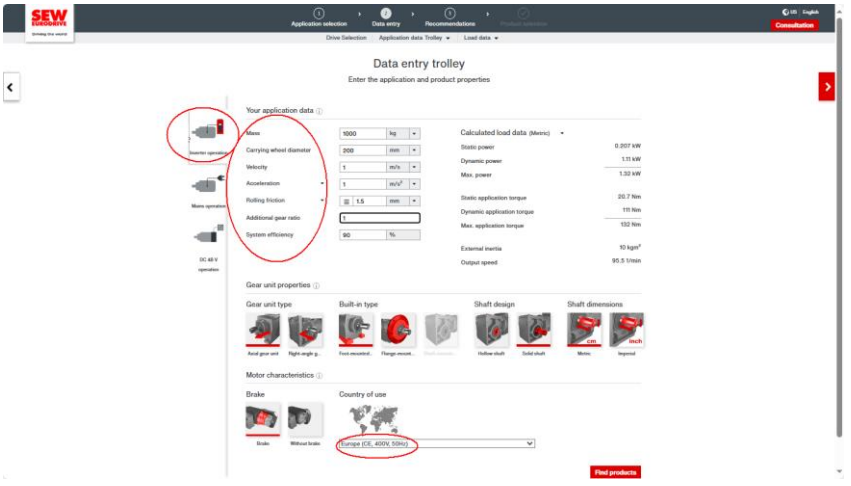
SEW Drive Selection: trolley with VFD



Need to specify:

- Mass
- Carrying wheel diameter
- Velocity
- Acceleration
- Rolling friction
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use

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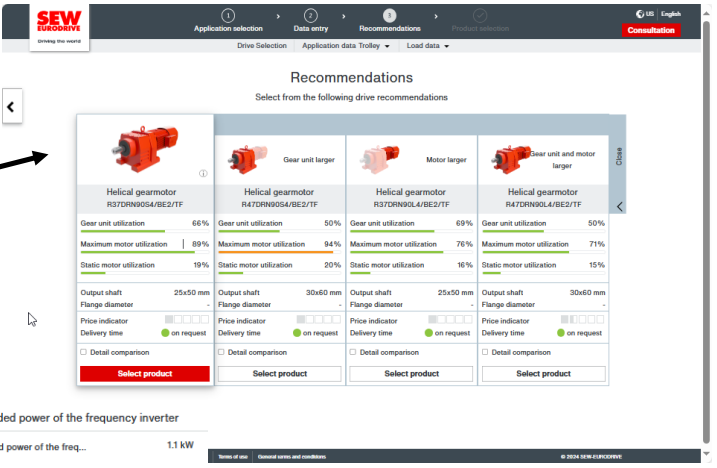
SEW Drive Selection: trolley with VFD

Helical gearmotor R37DRN90S4/BE2/TF

Catalog designation	R37DRN90S4/BE2/TF
Rated motor speed	1455 1/min
Output speed	93 1/min
Overall gear ratio	15.6
Output torque	112 Nm
Maximum permitted output torque	200 Nm
Service factor SEW	1.8
Permitted output overhung load w...	3630 N
Motor power	1.1 kW
Braking torque	14 Nm



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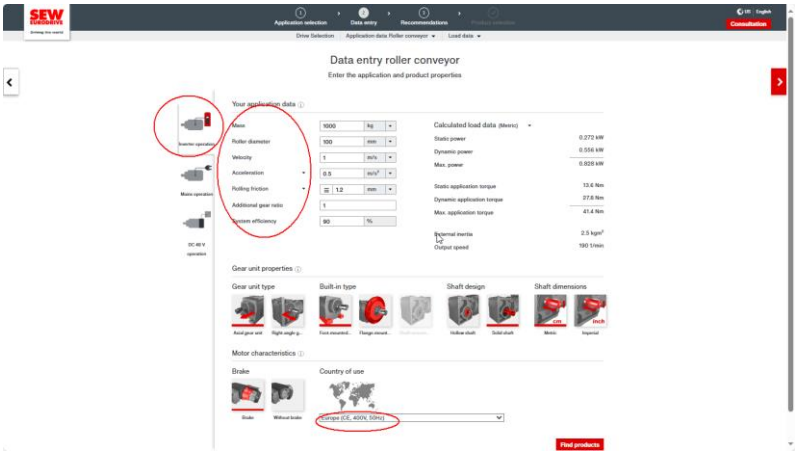
SEW Drive Selection: roller conveyor with VFD

Need to specify:

- Mass
- Roller diameter
- Velocity
- Acceleration
- Rolling friction
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use



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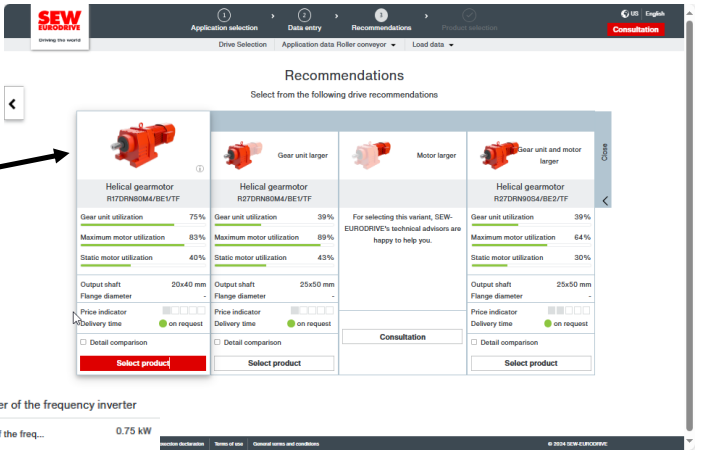
SEW Drive Selection: roller conveyor with VFD



Helical gearmotor R17DRN80M4/BE1/TF

Catalog designation	R17DRN80M4/BE1/TF
Rated motor speed	1440 1/min
Output speed	205 1/min
Overall gear ratio	7.04
Output torque	35 Nm
Maximum permitted output torque	55 Nm
Service factor SEW	1.55
Permitted output overhung load w...	1180 N
Motor power	0.75 kW
Braking torque	10 Nm

Recommended power of the frequency inverter

Recommended power of the freq... 0.75 kW

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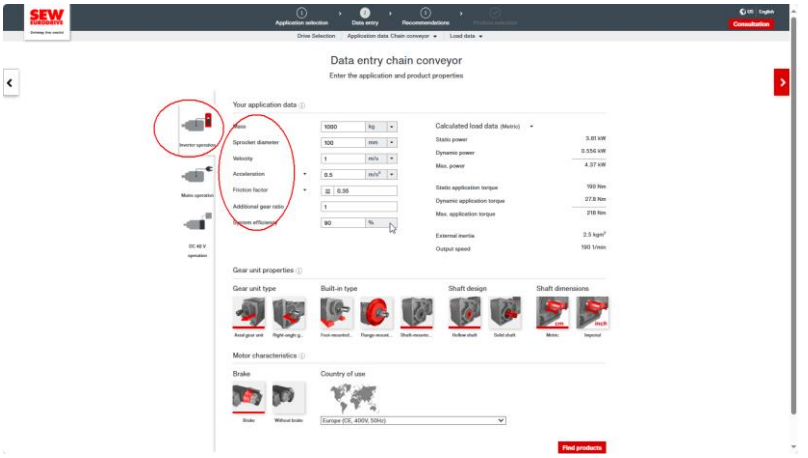
SEW Drive Selection: chain conveyor with VFD



Need to specify:

- Mass
- Sprocket diameter
- Velocity
- Acceleration
- Friction factor
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use

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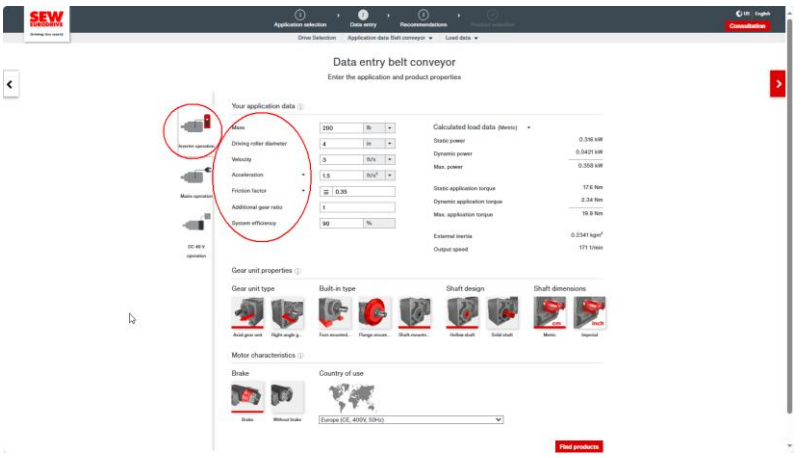
SEW Drive Selection: belt conveyor with VFD

Need to specify:

- Mass
- Driving roller diameter
- Velocity
- Acceleration
- Friction factor
- Additional gear ratio
- System efficiency

- Gear unit properties
- Motor characteristics
- Country of use



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