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Advantages at a glance

- Mechanically optimised machines - simpler and more compact
- More powerful and dynamic, more accurate and quieter
- More cost-effective in design, layout, operation and maintenance
  - More reliable
- Usable under clean room conditions

Where can direct drive technology be used to advantage?

- Loading and unloading systems
- Component placement (for example in the electrical industry)
- Parts handling and processing
- Manufacturing machines requiring high dynamic performance and precision
  - Biomedicine / Life sciences
- Semi-conductor and electronics manufacturing
  - Science, research & laboratory work
  - Plastic processing
- ... and everywhere that the highest demands are placed on increased production

The demand for product quality and machine output is constantly rising.

The direct integration of drive technology into the process - without any compliance or elasticity that reduces quality and is critical for control systems - allows for significant improvements in this area.

In some cases, electro-mechanical direct drives replace hydraulic solutions. The result is an environmentally-friendly solution that is also easier to install.

Direct and jerk controlled drive technology increases the availability of the machine.

Accuracy

Information on precision is defined in EN ISO 9283. Essentially, a distinction is drawn between point-to-point motion and motion along a path.

Position stiffness

A distinction is also drawn between static and dynamic stiffness.

Static stiffness - the capacity to maintain position under the effect of a permanently operating external force (for example processing forces).

Dynamic stiffness - behaviour under the effect of a transient force (jerk).

Settling times

Direct drives have very short settling times. Settling time - the time between first entering the positioning repeatability window and remaining within it definitively.
Linear motors

In the case of linear motors, electrical power is converted directly into linear motion. Synchronous linear servo motors are also available as torque motors in various styles, for example as a kit or as a complete solution.

Parker Hannifin offers all linear motor technologies.
- Iron-cored linear motors - LMI series
- Ironless linear motors - LMDT series
- Slotless linear motors - LXR and MX80
- Double-sided design (iron-cored) - BLMA

Conventional permanent magnet iron-cored linear motor

- Coils laid in grooves
- Lamination pack and adapter plate
- Temperature sensor
- Position sensor
- Single set of magnets

Ironless linear servo motor

- Ironless winding embedded in plastic
- Heat sink and adapter plate
- Dual set of magnets
- U-shaped iron back
- Hall sensors arranged at the forcer and a temperature switch integrated into the winding

Slotless linear motor

- Temperature sensor embedded in winding
- Aluminium housing / adapter plate
- Sheet pack
- Coils
- Magnets
- Iron back

Iron-cored linear motor in double-sided arrangement

- Coils
- Laminated plastic
- Permanent Magnets
- Magnetic flowlines

Torque motors

The typical features of a rotary direct-drive torque motor (rotary direct drive) are low speed of rotation and high torque. Torque motors have a relatively high number of poles and are available with a solid or hollow shaft. Eliminating the gearbox increases the dynamic performance of the direct drive.

Active cooling directly increases
- continuous output
- service life of the guidance mechanism and bearings
- achievable precision

Cooling mechanisms for direct drive systems

- Convection cooling
- Compressed air cooling
- Water cooling

Convection cooling is the simplest method, but also the least effective. On the other hand, water cooling is highly effective and the temperature can be well controlled. Compressed air is used in the low to medium power range or for short duty cycles.
Requirements for a servo controller for use in a direct drive system

- High dynamic performance with short scanning times (Ts = 5µs, 12x over-sampling)
- Flexible option for commutation (analogue+digital hall sensor system, auto-commutation, absolute encoder, distance-coded)
- Setpoint generation with jerk control
- Forward control of speed, acceleration, motor current and jerk
- Options for cogging and feedback error compensation
- Observer technology

In the case of direct drives, stiffness is achieved by feedback of the motor position signal to the position and speed control circuit. The lack of a mechanical reduction ratio causes the effects of external forces to be significantly greater than for conventional linear drives with rotary motors. Because of this, the quality of the position signal (resolution and precision) and the output capacity of the servo controller (scanning time, control algorithms used) are decisive factors in determining the level of position stiffness that can be achieved with direct drives.

Feedback devices for use with direct drives

- Magnetic
- Inductive
- Optical

Optical encoders offer the highest resolution and accuracy. By comparison, magnetic and inductively based position transducers are significantly more economical but offer considerably lower accuracy and resolution.

Because of the high interpolation rates that can be achieved in a digital controller, analogue sine-cosine signals are used to control position and speed instead of digital encoder signals. Often there is no need for a high-resolution optical encoder system. For the Compax3 digital servo controller, the interpolation resolution for analogue signals with a maximum of 1Vp-p is 14 bits, i.e. a transmitter signal period is subdivided into 16384 counts. This makes it possible to subdivide the pitch period of 1 mm (a typical value for magnetic and inductive transmitters) into approximately 62 nm internally to the controller. Compax3 can thus implement high-performance control schemes. Optical encoder systems are only required for tasks that are highly demanding in terms of dynamic performance, speed or multi-axis synchronism.

The most economic system for recording motor position is measuring magnetic flux by means of analogue Hall sensors. It is typically possible to achieve a repeatability of 0.1 mm for linear motors. Compax3 can achieve a position resolution of 2.56 µm with an interpolation resolution of 14 bits at a motor magnet spacing of 42 mm.

Direct drive 2axis NC milling head for the woodworking and machine tool industry

High dynamic performance, reproducible quality and a high demand for precision are criteria that led to the decision to use torque motors. Up to 4 motors are used, the 2 motors of the C axis being synchronised in torque by means of a drive bus with real-time capability.

- High transport speeds
- Compact design of the milling head
- Economical design based on a shared measurement system

Commutation of the direct drive

With conventional drives, absolute information about motor speed is generally available for commutation of the motor. With direct drives, this is usually not possible because of the incremental feedback systems that are generally used. Motor commutation can also be implemented for incremental feedback systems with three additional digital Hall sensors. However, this sensor system is specially related to the magnetic period of the motor. This option is not available from all motor manufacturers. If digital Hall sensors are not available, then the servo controller as well as the Compax3 must determine the commutation angle internally each time the system is turned on. Analogue Hall sensors provide an absolute position reference for position measurement. The commutation angle is derived from incremental position information.
State-of-the-art control technology - the decisive factor in the successful use of direct drive systems

The use of direct drives places high demands on control systems. There are no isolating elements in the system - external influences have a direct effect on the control circuit. Parker relies on the structure of cascaded control of motor current, motor speed and motor position to control direct drives. Feedforward control of speed, acceleration and motor current is important to minimise the tracking error.

A highly effective method for further increasing tracking performance with highly dynamic motions is feedforward control of jerk within the controller cascade.

One of the most effective methods of improving system behaviour with a direct drive is profile generation with feedforward jerk control. This reduces the mechanical load considerably, minimises the excitation of mechanical resonance and allows for optimal tracking performance (minimum tracking error).

If setpoint generation and the individual control circuits are running at different scanning times, fine interpolation of the position setpoint and feedforward control signals is required to adjust to the higher scanning frequency of the control algorithms.

The scanning frequency of the three control circuits has a considerable effect on the level of stiffness that can be achieved by the drive. Because of the lower system time constants that can be achieved with direct drives, the controller must also handle higher mechanical resonance frequencies. This requires high bandwidth in the control circuits. The current control and feedback loop of Parker servo controllers therefore operates at a scanning frequency of 16 kHz and the speed and position controller at 8 kHz. Setpoint generation occurs at 2 kHz.

Parker drive technology is flexible!

- Compatible with most feedback systems on the market
- Available for operation with third-party motors
- No limitations in terms of applications

Feedforward jerk control as implemented by Parker Hannifin offers the following advantages

- The maximum allowable mechanical force is accurately controlled
- Mechanical resonance is suppressed
- High acceleration rates ensure optimal cycle times

Ask for our catalogue ...
www.parker-eme.com
sales.hauser@parker.com
Control systems from Parker Hannifin - available as a PC-based or standalone solution

ACROLOOP - Motion and contouring control for PCs
- Simultaneous communication between control system, PC and drive
- Electronic gearbox
- Segmented curves
- Simultaneous electronic curves, gearboxes and manual operation
- Nurbs / complete curve lines
- Spline interpolation
- 3D arcs
- Tangential axes
- Dynamic „look-ahead“ function
- Notch filter

C3 powerPLmC - The most powerful PLC for Motion Control
- Automation platform for combined PLC, Motion Control and visualisation tasks
- Internationally recognised standards in programming (IEC61131-3), communication and interfaces
- 1,000 IL-instructions performed in less than 100 µsec
- Remote diagnostics Ethernet
- OPC-Interface
- WebServer
- Powerful project and library management
- Standard integrated PLCopen Motion Control libraries
- Drive interface
- Optimised for use as a multi-axis motion control system
- Technology functions (such as electronic cam)

Actuators
- DC Motors
- Step motors
- Servo Motors
- Torque Motors
- Linear Motors (Kit)

Controls
- Current PWM
- Fieldbus I/O
- TBL
- Siemens S7
- Compax3
- PIO
- POP

Motion Control
- Internet
- Ethernet
- Operation & HMI
- CANopen
- CANopen with SYNC-Telegram
- VIX
- Linear motor actuator (System)
Direct-drive robots for industrial use

- 5-axis system with torque motors
- Parker Hannifin supplies the motors and drive technology
- Compact structure of the system
- High dynamic performance and precision
- Simplified assembly
- Reduced overhead for maintenance

Direct-drive injection moulding machines

Hydraulic systems are increasingly being replaced by electro-mechanical drives in today's injection moulding machines. The benefits include simplified maintenance and the significantly simpler electrical power supply system. Typical applications are clamping, injection, plastification and ejection.

- High dynamic performance
- Reproducible product quality
- Simplified assembly
- Reduced overhead for maintenance
- Simplified power supply system

Machines for manufacturing tyres & rubber products

In the latest-generation machines used to manufacture tyres, hydraulic systems are generally replaced by electro-mechanical drives. In particular, high product quality that can always be reproduced has been a decisive factor in the transition to torque motors.

- High dynamic performance
- Reproducible product quality
- Simplified assembly
- Reduced overhead for maintenance
- Simplified power supply system

Markets and Applications

Mechanical engineering
- High-speed tasks
- Grinding and laser processing
- Precision processing
- Woodworking
- Welding
- Sheet treating and processing
- Printing machines
- Textile machine construction
- Packaging machines

Transport & Handling
- Pick & Place
- Elevating systems
- Supply and Loading
- Cartesian & gantry robots

Plastic processing
Injection moulding

Semi-conductor manufacturing & electronics
- Insertion machines
- Lithography
- Circuit board processing
- Wafer processing centres
- IC checking and testing
MARKETS AND APPLICATIONS

Electron-beam processing for glass polarisation

To transfer the required pattern, the glass polariser is moved in defined steps relative to the electron beam under a structuring mask. In this special application, linear motors must also be operated in a high vacuum. In this machine, a Parker slotless linear motor is used.

- High dynamic performance and precision
- Short settling time to come into position
- Minimal overhead for maintenance

Direct-drive automatic IC testing devices for the semiconductor industry

Linear motors ensure faster, accurate positioning of ICs under the fixed measurement head together with faster throughput. Three Parker ironless linear motors are used in this automatic device with their outstanding power-to-weight ratio.

- Compact structure of the system
- High dynamics, fast settling time and precision
- Low weight
- Minimal cogging

Direct-drive CT and PET scanners

Linear motors are used with the new generations of computer tomograph (CT) and PET scanners to move patients. The main consideration is safe and accurate movement. Linear motors allow smooth movement of the bed, including when the motor is de-energised.

- Compact structure of the system
- High safety and precision
- Constant-speed travel during the scanning process

Life sciences, biological and medical technology

- Genetic and medical research (e.g. laboratory automation)
- Micro arrays
- Liquid handlers
- Loading and unloading systems
- Computer tomographs
- PET scanners

Renewable energy

- Wind power systems
- Solar power systems
There is a distinction between kit motors and complete systems for direct drives. Complete systems come as Plug and Play units. In addition to the actual motor, additional elements such as the feedback device, bearing system and cooling are already integrated and fully compatible with each other in these systems.

In linear or rotary kits the motor is ideally “embedded” in the machine. In contrast to a complete system, the motor is a fundamental element of the overall design. The feedback device, bearing system and methods of cooling are selected after taking into consideration the specific conditions. Complete systems can be used if there is a desire to take advantage of the benefits of direct drive systems without additional design overhead. This is especially true in the case of special machine construction and setting up testing systems.

**Design elements of a direct drive**
- Machine mechanics with coupling system
- Measurement system with resolution and connection method
- Servo amplifier

**Questions on performance**
- Duty cycle
- Speed
- Acceleration
- Repeatability, accuracy, absolute precision
- Stability of speed and position
- Tracking accuracy

**Questions on mechanics**
- Cable guiding, cable carrier chain
- Oscillation behavior, natural frequency
- Arrangement of the motor
- Heat dissipation and cooling
- Horizontal or vertical application
- Mechanical limits (speed and acceleration)
- Movable mass
- Friction and frictional forces

Parker offers full support during product development.

**Questions on the motor**
- Motor concepts
- Special designs (including design of magnetic path, carriage head, sensor system)
- Type of cooling

**Questions on the environment**
- Ambient temperature
- Maximum permissible motor temperature
- EMC
- Drives designed for use in clean rooms

**Attraction forces between forcer and magnet rails of linear motors**
- Attraction forces of approx. 200 kN/m² may occur when the forcer is energised
- Either the guide mechanism or the mechanical structure must withstand these forces
- These forces are constant, i.e. independent of the generated force.

**Danger caused by deformation and unacceptable transverse loads on guide mechanisms**
- Symmetrical arrangement of motors to each other
- Arrangement of motors to compensate for the effect on the bearings
**LINEAR SERVO MOTOR KITS - LMDT / LMI**

### Ironless linear servo motors

<table>
<thead>
<tr>
<th>Model &quot;LMDT&quot; (ironless)</th>
<th>Continuous force [N]</th>
<th>Peak force [N]</th>
<th>Constructional width of the motor track [mm]</th>
<th>Installation height of the motor track [mm]</th>
<th>Flange length [mm]</th>
<th>Weight of coil [kg]</th>
<th>Weight of magnetic track [gr/mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>26 .. 107</td>
<td>84 .. 337</td>
<td>19.05</td>
<td>38.1</td>
<td>91.4 / 152.4</td>
<td>0.099 .. 0.399</td>
<td>2.98</td>
</tr>
<tr>
<td>1500</td>
<td>40 .. 160</td>
<td>127 .. 507</td>
<td>28.7</td>
<td>45.5</td>
<td>91.4 / 152.4</td>
<td>0.104 .. 0.498</td>
<td>5.51</td>
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<tr>
<td>2000</td>
<td>71 .. 360</td>
<td>222 .. 1125</td>
<td>34.8</td>
<td>86.9</td>
<td>91.4 / 152.4</td>
<td>0.204 .. 0.930</td>
<td>16.1</td>
</tr>
<tr>
<td>2800</td>
<td>182 .. 1463</td>
<td>912 .. 7308</td>
<td>63.5</td>
<td>180.1</td>
<td>91.4 / 152.4</td>
<td>0.82 .. 6.64</td>
<td>52.1</td>
</tr>
</tbody>
</table>

### Linear servo motors with iron

<table>
<thead>
<tr>
<th>Model &quot;LMI&quot; (iron-cored)</th>
<th>Continuous force(^{(1)}) [N]</th>
<th>Peak force [N]</th>
<th>Constructional width of magnetic carrier [mm]</th>
<th>Installation height of magnetic carrier [mm]</th>
<th>Installation length of magnetic carrier [mm]</th>
<th>Installation height of coil [mm]</th>
<th>Length of coil [mm]</th>
<th>Weight of coil [kg]</th>
<th>Weight of magnetic track [kg/m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>017</td>
<td>52</td>
<td>210</td>
<td>45</td>
<td>10.5</td>
<td>64 / 96 / 160</td>
<td>25</td>
<td>180</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>035</td>
<td>120 .. 550</td>
<td>430 .. 1000</td>
<td>70</td>
<td>11.5</td>
<td>64 / 96 / 160</td>
<td>25 / 45.8</td>
<td>180 / 210 / 395</td>
<td>1.4 .. 5.5</td>
<td>4.5 / 4.7</td>
</tr>
<tr>
<td>052</td>
<td>190 .. 380</td>
<td>640 .. 1290</td>
<td>90</td>
<td>11.5</td>
<td>64 / 96 / 160</td>
<td>25</td>
<td>180 / 340</td>
<td>1.9 .. 3.5</td>
<td>6.0</td>
</tr>
<tr>
<td>070</td>
<td>280 .. 1820</td>
<td>870 .. 3000</td>
<td>100</td>
<td>11.5</td>
<td>64 / 96 / 160</td>
<td>25 / 45.8</td>
<td>180 / 340</td>
<td>2.5 .. 14.7</td>
<td>7.1 / 10.1 / 7.5</td>
</tr>
<tr>
<td>105</td>
<td>430 .. 2830</td>
<td>1300 .. 4500</td>
<td>140</td>
<td>11.5</td>
<td>64 / 96 / 160</td>
<td>25 / 45.8</td>
<td>180 / 340</td>
<td>3.4 .. 14.1</td>
<td>10.1 / 10.8</td>
</tr>
<tr>
<td>140</td>
<td>590 .. 3800</td>
<td>1700 .. 6000</td>
<td>180</td>
<td>13.5</td>
<td>64 / 96 / 160</td>
<td>25 / 45.8</td>
<td>180 / 340</td>
<td>4.4 .. 27.0</td>
<td>15.9 / 15.9 / 16.8</td>
</tr>
<tr>
<td>210</td>
<td>2100 .. 6000</td>
<td>3000 .. 9000</td>
<td>250</td>
<td>13.5</td>
<td>64 / 96 / 160</td>
<td>49.8</td>
<td>222 / 407 / 592</td>
<td>16.0 .. 45.7</td>
<td>27.9</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Ambient temperature 20°C, self-cooling, coil temperature 130°C, good cooling connection
Application using the LXR

Four-axis system for positioning a laser in photocell manufacturing

A solar cell manufacturer uses a multi-axis positioning device to produce a holographic pattern in a glass plate by means of a laser beam. This system operates with four movement axes: three axes for linear movements (XYZ) and one axis for rotary movement. Parker LXR linear motor tables are used.

- Short settling time
- No vibration or oscillating
- Acceleration > 3g
- High system stiffness

Options in the appendix, dependent on product series

(1) Higher accuracy due to transmitter with the highest achievable resolution measured at the center of the carriage at 20°C without an effective load. Unit mounted on an even granite plate (1µm / 300mm)

System solutions from Parker

- LXR Linear motor table for precision applications
- BLMA Linear motor actuator for dynamic handling tasks
- MX80 Small system optimised for applications in the field of Life Sciences
Torque Motors (complete system solution)

<table>
<thead>
<tr>
<th>Model &quot;STK&quot;</th>
<th>Continuous torque(^1) [Nm]</th>
<th>Peak torque(^2) [Nm]</th>
<th>Length of rotor [mm]</th>
<th>Nominal current [A]</th>
<th>External diameter [mm]</th>
<th>Effective internal diameter [mm]</th>
<th>Internal diameter [mm]</th>
<th>Length of casing [mm]</th>
<th>Number of pole pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td>145 STK</td>
<td>14 .. 47</td>
<td>43 .. 172</td>
<td>86 / 140 / 194 / 248</td>
<td>2.3 .. 15.7</td>
<td>145</td>
<td>78.5</td>
<td>56</td>
<td>119 / 173 / 227 / 281</td>
<td>12 .. 48</td>
</tr>
<tr>
<td>190 STK</td>
<td>36 .. 111</td>
<td>94 .. 372</td>
<td>68.25 / 104.5 / 140.75</td>
<td>5.0 .. 23.3</td>
<td>190</td>
<td>98</td>
<td>72</td>
<td>103.5 / 140 / 176.25</td>
<td>12 .. 48</td>
</tr>
<tr>
<td>300 STK</td>
<td>96 .. 295</td>
<td>320 .. 1281</td>
<td>27.5 / 55 / 82.5 / 110 / 137.5 / 165</td>
<td>7.3 .. 69.5</td>
<td>303</td>
<td>228</td>
<td>190</td>
<td>87.5 / 115 / 142.5</td>
<td>12 .. 48</td>
</tr>
<tr>
<td>400 STK</td>
<td>225 .. 700</td>
<td>724 .. 2895</td>
<td>27.5 / 55 / 82.5 / 110 / 137.5 / 165</td>
<td>15.8 .. 45.6</td>
<td>404</td>
<td>306</td>
<td>258</td>
<td>100.5 / 128 / 155.5</td>
<td>12 .. 48</td>
</tr>
<tr>
<td>500 STK</td>
<td>210 .. 640</td>
<td>587 .. 2348</td>
<td>27.5 / 55 / 82.5 / 110 / 137.5 / 165</td>
<td>7.7 .. 112.8</td>
<td>502</td>
<td>403</td>
<td>350</td>
<td>93 / 120.5 / 148 / 175.5 / 203 / 230.5</td>
<td>12 .. 48</td>
</tr>
<tr>
<td>800 STK</td>
<td>610 .. 2708</td>
<td>1543 .. 9258</td>
<td>27.5 / 55 / 82.5 / 110 / 137.5 / 165</td>
<td>14.9 .. 110</td>
<td>795</td>
<td>689</td>
<td>630</td>
<td>112.5 / 140 / 167.5 / 195 / 222.5 / 250</td>
<td>12 .. 48</td>
</tr>
</tbody>
</table>

(1) Ambient temperature 20°C; Increase in temperature of the winding 120°C, typical torque at standstill or low speed; good cooling connection
(2) Cold motor 20°C; peak torque up to 300 / 1000 rpm available

\(\Omega_B\) External diameter  
\(\Omega_{De}\) Effective internal diameter  
\(\Omega_C\) Internal diameter  
LB Length of casing  
R Length of rotor
---

**Manufacturing automation - filling systems**

Bottles pass through numerous stations before they are ready for delivery. Machines of this type require high reliability and dynamic performance. In addition, sourcing the complete range of automation equipment from a single manufacturer is a significant advantage.

- High reliability
- High cycle rates
- Maintenance-free operation
- Everything included with delivery

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**Process automation - Machines for paper production**

Machines for producing paper generally run 24 hours a day. Downtimes and machine maintenance time must be kept to a minimum. Very tight synchronisation ensures optimal quality.

Also in this case as well, there is a need to receive the complete range of products from a single manufacturer.

- Tight synchronisation
- No vibration
- Maintenance-free operation
- Everything included with delivery

---

**Model “ST”**

<table>
<thead>
<tr>
<th>Model</th>
<th>Continuous torque</th>
<th>Peak torque</th>
<th>Nominal current</th>
<th>Speed</th>
<th>External diameter</th>
<th>Internal diameter</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST 145</td>
<td>14 .. 47</td>
<td>43 .. 172</td>
<td>2.3 .. 15.7</td>
<td>500 / 1500</td>
<td>147</td>
<td>60</td>
<td>212 / 266 / 320 / 374</td>
</tr>
<tr>
<td>ST 190</td>
<td>36 .. 111</td>
<td>94 .. 372</td>
<td>5.0 .. 23.3</td>
<td>500 / 1000 / 1500</td>
<td>190</td>
<td>75</td>
<td>235 / 307.5 / 380 / 452.5</td>
</tr>
</tbody>
</table>

(1) Ambient temperature 20°C; increase in temperature of the winding 120°C typical torque at standstill or low speed; 150 / 200 mm - flange
(2) cold motor 20°C; peak torque up to 300 / 1000 rpm available
Precision with resolver ±1 arc min

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Parker Hannifin GmbH&Co.KG
Electromechanical Automation
Parker Hannifin is ...

- a leading manufacturer of components and systems for motion automation
- at home in all the relevant technologies - hydraulics, electro-mechanics and pneumatics
- a global company - with worldwide service and 24-hour availability

Parker Hannifin ...

- employs 45,000 people
- has a sales volume of more than 6 billion US$
- has 210 manufacturing and development sites worldwide
Parker Hannifin Europe ...

- develops and manufactures electromechanical components and systems
- plays a pioneering role in direct drive technology
- offers a comprehensive range of products for complete machine and system automation
Parker Hannifin - your specialist for direct drive technology

Medical Technology

Lifts

Printing Machines

Wind Energy Systems

Robotics

Electrical Industry

Testing & Diagnosis