WHAT ARE THE REQUIREMENTS FOR SEALS AND DAMPING ELEMENTS IN ROBOTICS APPLICATIONS? A WHITE PAPER

INNOVATING TOGETHER

FREUDENBERG
SEALING TECHNOLOGIES

Content

Executive Summary

Robotics: This term encompasses a value chain that ranges from industrial and articulated-arm robots to cobots and autonomous systems used in warehouse logistics – and it also includes the design of humanoid robots intended to approximate the full range of human capabilities. Each of these process chains involves customized robot mechanics integrated with state-of-the-art models using artificial intelligence and advanced sensor technology. In reports on the diverse robotics markets and technologies, two aspects rarely get mentioned: seals and dampers, without which mechanical motion would not even be possible. Seals keep lubricants where they are needed. Damping elements, in contrast, absorb oscillations and vibrations and enable optimal power transmission. This white paper outlines the robotics market segments with groundbreaking developments – and it identifies the materials, sealing profiles and surface solutions best suited to make this evolution possible.

Introduction

“Technological progress always emerges when smart people seek solutions to eliminate risks and optimize processes. In robotics, the revolutionary advances of recent decades clearly demonstrate what we can achieve when we think out of the box. Today, medical robots assist in open-heart surgery and tumor operations. At the same time, service robots have become an increasingly familiar presence in private households, whether outdoors for lawn mowing or indoors for floor cleaning.

All these robotic technologies rely on sealing solutions, damping elements and application-specific small-scale batteries that support their use under diverse system requirements and environmental conditions. For more than 30 years, we at Freudenberg Sealing Technologies have worked closely with our industrial customers to develop innovative materials and sealing profiles that are needed for dynamic progress in robotics. Building on this materials expertise, we now also develop and manufacture a broad range of damping elements and electronic components for battery modules. In all these areas, development engineers must work closely with materials and design specialists so we can implement product ideas and turn them into market-ready solutions within a short time.

At Freudenberg Sealing Technologies, we work with our customers to actively shap market trends and establish new economic benchmarks, including in the development of humanoid robots. Unlike traditional robots, supporting robotics to not only adapt controlled indoor workspace but also get ready to work in complicated, challenging open workspace in close future will soon become our new missions. We pursue a modular, holistic approach in robotics development and place strong emphasis on cross-industry information exchange. With this white paper, we invite you to deepen your understanding of sealing and damping solutions for robotics applications and enter into dialog with us as we continue to advance key aspects of robotics together.”

Hunter Cheng,
Global Segment Manager Robotics, Freudenberg Sealing Technologies

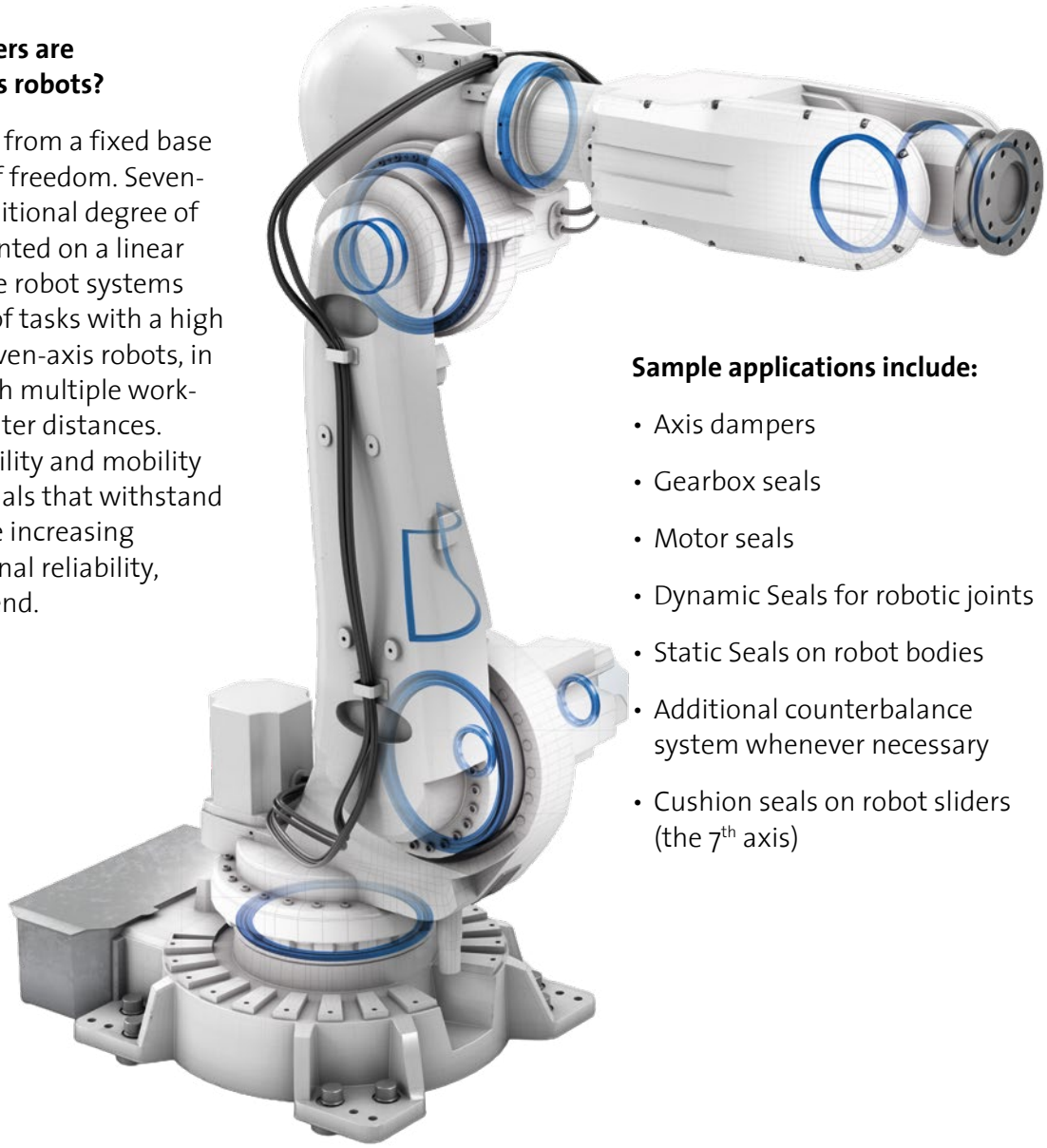
Hunter Cheng

What characterizes different types of robots and where are seals and dampers used?

The field of robotics covers the design, development, construction and use of robots. It integrates elements from mechanics, electronics, computer science and mathematics. In essence, robotics applications are systems that can perceive their environment, make decisions and execute defined actions. This requires robots to have sophisticated sensors that collect information about their surroundings. They use actuators to perform movements or actions – such as electric motors in joints and wheels, powerful hydraulic or pneumatic drives in larger systems, and highly specialized grippers on robotic arms. Complex control systems are needed to coordinate these decisions and movements. In the following robotics segments, high-performance seals and damping elements are essential to provide energy-efficient battery operation and ensure that actuators can perform the desired activities:

Which seals and dampers are needed by 6- and 7-axis robots?

Six-axis robots operate from a fixed base and have six degrees of freedom. Seven-axis robots gain an additional degree of freedom by being mounted on a linear guidance system. These robot systems perform a wide range of tasks with a high degree of flexibility. Seven-axis robots, in particular, can approach multiple workstations and cover greater distances. This high level of flexibility and mobility requires flexible materials that withstand mechanical loads while increasing efficiency and operational reliability, especially in the front end.



Sample applications include:

- Axis dampers
- Gearbox seals
- Motor seals
- Dynamic Seals for robotic joints
- Static Seals on robot bodies
- Additional counterbalance system whenever necessary
- Cushion seals on robot sliders (the 7th axis)

An interactive graphic with integrated sealing profile information is available here:

www.fst.com/de/maerkte/robotik/6-achs-roboter/

Which seals and dampers are needed by AGVs/AMRs?

Automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) are driverless transportation systems. They automate processes in warehouses and production facilities and offer significant growth potential in logistics applications. AGVs follow predefined routes and are therefore ideal for standardized processes. AMRs are much more flexible. They use application-specific sensor systems and artificial intelligence to act independently and flexibly in real time. They can avoid obstacles, for example. This makes them ideal for dynamic storage processes and variable production environments. Operating these systems requires robust materials and designs that can withstand dusty and damp environments. Sample applications include:

Sample applications include:

- Wheels and shock absorbers
- Seals for car bodies and wheels
- Motor seals
- Gearbox seals
- IPSR (Ingress Protection Seals for Robotics) for waterproofing
- Waveguide Antenna for AMR to allow 3D scanning and obstacle detection

An interactive graphic with integrated sealing profile information is available here:

https://www.fst.com/de/maerkte/robotik/agvs/

Which seals and dampers are needed by cobots (collaborative robots)?

Cobots, widely recognized by their 4-axis structure, are specifically designed to work directly alongside humans in shared workspaces. In industrial environments, they handle repetitive or physically demanding tasks, relieving employees while also improving the quality of work. Comparing with the commonly seen industrial robots, Cobots are lightweight robots. They significantly increase efficiency and productivity in industrial processes because they can safely interact with people without requiring protective equipment. They also offer high flexibility and can perform a wide range of tasks in different work environments. For reliable operation, cobots require specific sealing geometries and damping elements that combine high wear resistance, flexibility and temperature stability.

Sample applications include:

- Seals for the entire robot arm
- Gearbox seals
- Elastic shock absorbers
- Motor seals
- Hygienic seals for direct human touch
- IPSR (Ingress Protection Seals for Robotics) for waterproofing

A graphic with integrated sealing solutions and materials is available here:

https://www.fst.com/de/maerkte/robotik/cobots/

Which seals and dampers are needed by Delta robots?

Delta robots, also known as parallel-link robots, consist of three independent arms arranged in an isosceles triangle (Δ – delta in Greek) as a parallel kinematic system. They have three degrees of freedom. Their design makes delta robots industrial all-rounders – it eliminates the need to move the downstream mass of links and drives, as each actuator connects directly to the tool carrier. This low moving mass allows them to execute movements with very high dynamics and precision. Consequently, manufacturers frequently use delta robots for pick-and-place applications as well as for assembly and packaging processes with high cycle rates. These applications require high-performance seals and dampers that prevent leakage and reduce maintenance effort. .

For example:

- Gearbox seals
- Motor seals
- Seals for a static base
- Vibration dampers

A graphic with integrated sealing solutions and materials is available here:

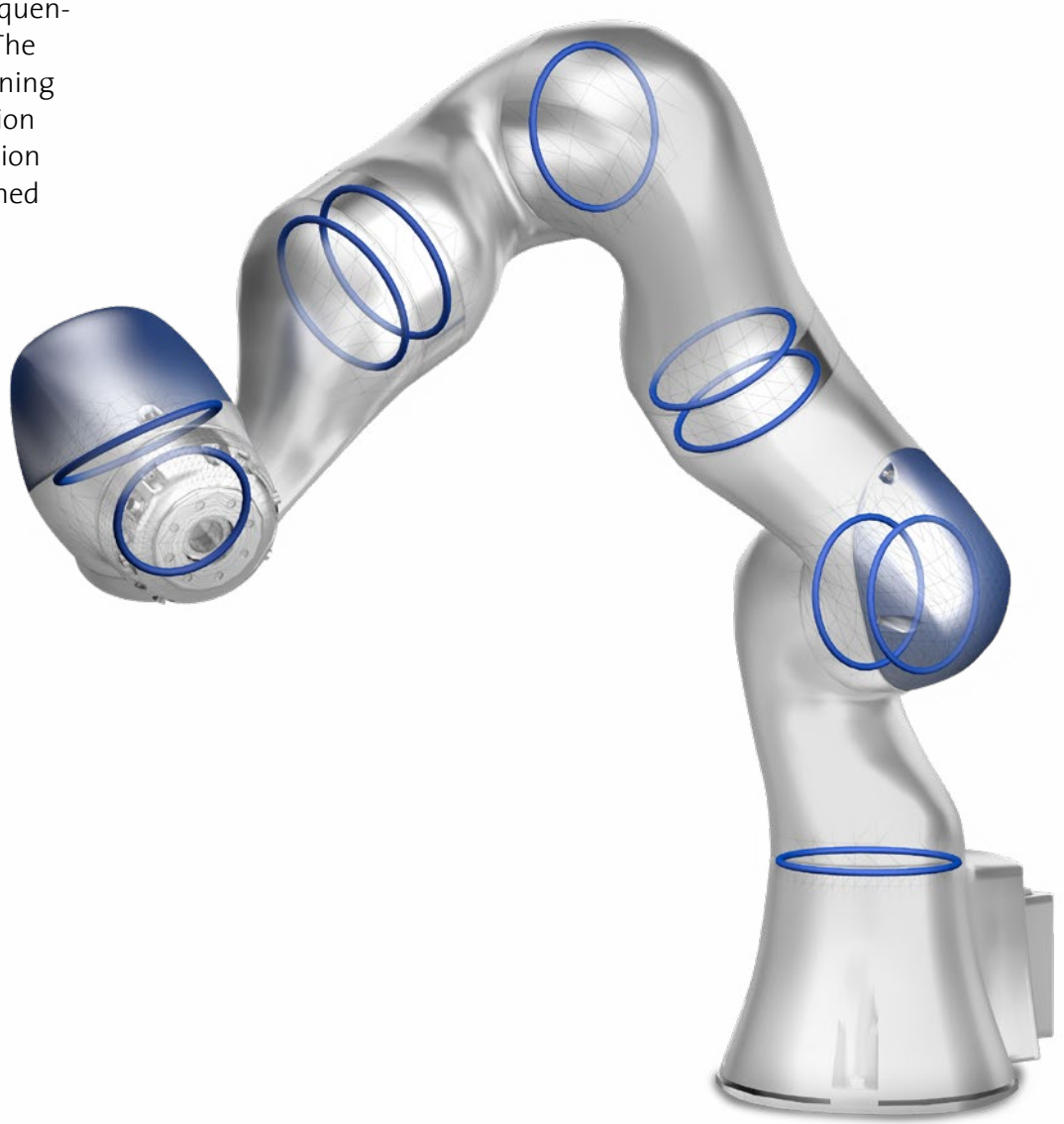
https://www.fst.com/de/maerkte/robotik/delta-roboter/

Which seals and dampers are needed by robots with articulated or buckling arms?

Articulated robots are distinguished by multi-axis joint structures that enable flexible movements and performance in three-dimensional space. Their serially connected axes allow these industrial robots to execute complex motion sequences with high precision, making them suitable for a variety of applications. The perfect combination of fine mechanical precision and adaptive motion planning makes articulated robots an ideal solution for a wide range of dynamic motion tasks in automated processes. The environmental conditions of the application determine which materials are optimally suited to support the heavily strained joint functions.

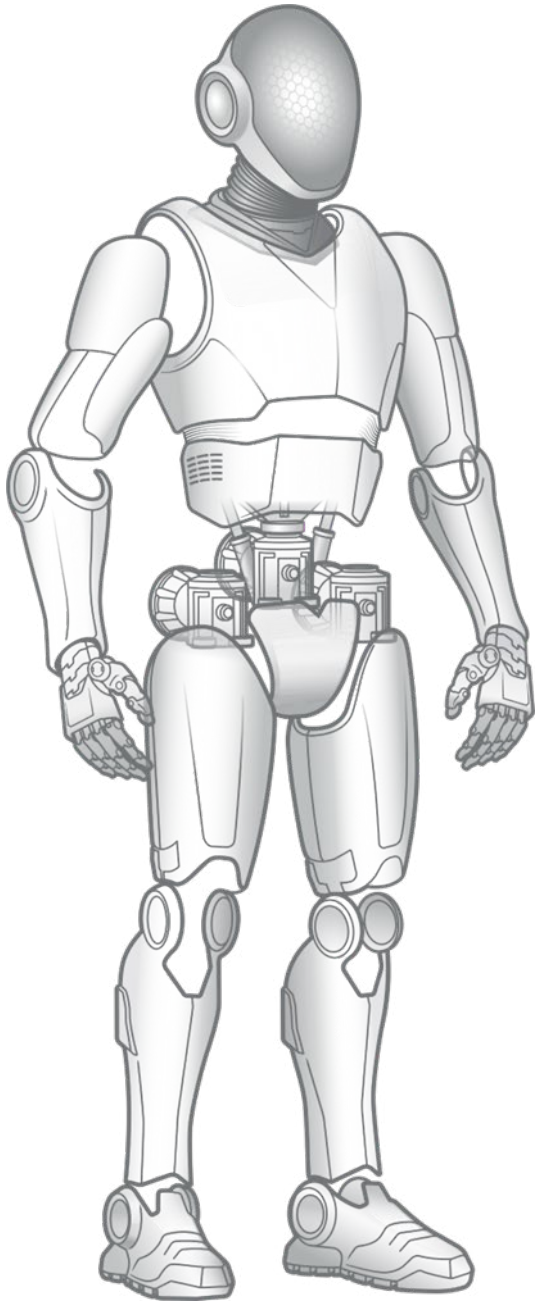
The following are required:

- Seals for robot grippers/end effectors
- Seals for rotatory joints
- Seals for translational joints
- Joint dampers
- Additional seals for end effector / gripping unit adapters whenever necessary



Which seals and dampers are needed by humanoid robots?

Humanoid robots are modeled on the human body and its motion capabilities in both appearance and mechanical performance. At present, there are steep learning curves in the areas of electronic components and energy supply, thermal management and sensor technology. In the future, general-purpose humanoid robots are expected to operate in a wide range of environments without requiring any adaptations of existing framework conditions. To achieve this, they must be capable of dynamically stable operation. A typical humanoid features a head, a torso, two arms with hands or grippers and two legs with feet, or an alternative mobility system, such as three wheels. The highly complex mechanics of humanoids require a wide range of seals, damping elements and sensor materials. Durable and robust materials with specific designs that ensure consistently low friction are particularly important here.



For example:

- Damping elements for different actuators
- Seals for drive units
- Seals for battery modules
- Seals for dexterous hand assemblies including wrists and finger joints
- Compact and flat wafer seals used in limited space to keep lubrication

The application areas for high-performance seals mentioned here will be addressed in detail in the next chapter.

You can already find links to news portals here.

Which seals and dampers are needed by SCARA robots?

SCARA robots (Selective Compliance Arm for Robotic Assembly) are a specific class of industrial robots. They feature one horizontal linear axis and three rotational axes, providing four degrees of freedom. Their joints and segments are arranged in a serial kinematic chain or row – with each joint directly connected to the preceding and following segment. SCARA robots can reach objects within a defined working area and process them at high speed. They stand out with their high precision and speed, properties which lead to their frequent use in manufacturing and assembly processes. These demanding applications primarily require sealing and damping elements with low friction and high wear resistance.

For example:

- Dampers for shoulder joints and connectors
- Motor seals
- Gearbox seals
- Static seals for upper and lower base covers

A graphic with integrated sealing solutions and materials is available here:

https://www.fst.com/de/maerkte/robotik/scara-roboter/

Which seals and dampers are needed by service robots?

Service robots are not directly involved in industrial production processes. Instead, they perform simple and defined services for people. Household and garden robots now roll across homes and lawns all over the world. Their drive and steering wheels connect via axles and adapt to changing ground conditions. The same is true for transport and delivery robots, information and navigation robots, as well as care robots. These applications require robust seals and dampers that resist cleaning agents, moisture, and dust. At the same time, they must ensure mobile power transmission and the leak-free operation of charging stations.

For example:

- Seals for drive elements
- Motor seals
- Seals for service stations
- Wheels and shock absorbers
- eCON for safe grounding to avoid bearing damage due to electrical discharge

Following this overview, we will focus on the robotics areas that are currently advancing with the most momentum. We will also list all the requirements for materials, sealing and damping solutions described above: for cobots and humanoid robots. This is where pioneering technological concepts are combined with established materials expertise. Let’s zoom in:

Which materials are suitable for the dynamic loads encountered by seals and dampers in cobots and humanoid robots?

These areas of robotics focus on a perfect coordination of energy and thermal management, optimally generated torques and the ideal power transmission for rotating and linear joint functions and end effectors at the end of the robot arm (EOA – End of Arm). In other words, on mechanical interfaces. In a wide range of environmental conditions, damping elements and sealing solutions are essential components of all body joints, wrist joints and battery units with integrated electronics. For cobots and humanoid robots that work closely with people, excessive friction in even a single joint can delay the activation of safety shutdown mechanisms. To prevent this, Freudenberg Sealing Technologies combines specially developed sealing geometries and damping designs with application-specific materials that ensure consistently low friction over long time periods. Here are examples of different applications:

Battery modules – Thermal management and operational safetyt

Battery modules combine battery cells connected in series or parallel to provide the available energy capacity of the robotic system. They integrate a wide range of electronic components. Electrical connections link the battery cells to each other within a module inside protective housing. Ideally designed battery modules with precisely matched sealing solutions reduce the risk of thermal runaway and enable optimum heat and energy management for the sensitive humanoid electronics. At the same time, seals must prevent the ingress of moisture and dust while minimizing damage caused by vibrations and shocks. This requires the following sealing components::

Coated busbar/conductor rail (busbar) – vulcanizable elastomers

Busbars are metallic current conductors, conductive tracks or collector rails in power electronics. Their rectangular cross-sections require a patented sealing concept. This is how the sealing arrangement works: It begins with a media-tight bond created by chemically pretreating the conductor surface with a primer and applying a specialized elastomer coating. This produces an intermediate layer that is bonded to the material. Next comes thermoplastic injection molding. Preferably, the elastic material used here is based on vulcanizable elastomers such as FKM, AEM, ACM, HNBR, NBR or EPDM. Depending on system requirements, companies may also use thermoplastic elastomers (TPE) to securely seal the edges.

Flame-barrier profiles – Thermoplasticse

The precise addition of fillers such as glass or carbon fibers can reinforce the mechanical stability of heat-resistant thermoplastics, so that they retain their protective properties even under enormous heat. The additional cross-linking of the plastic molecular chains ensures that the seal maintains its shape even under extreme conditions. Manufacturers can adjust the required material properties to the respective application, enabling reliable thermal management in battery systems for cobots and humanoids..

Pressure equalization valve – DIAvent® Mini

DIAvent® is a smart pressure equalization element for lithium-ion batteries. As in automotive applications, the hermetically sealed lithium-ion battery housings in robotics require dedicated solutions for the needed pressure compensation. This valve integrates multiple functions into a single component: pressure equalization during normal operation, fast and reliable opening for emergency degassing in the worst-case scenario – the thermal runaway of a cell – and closing after pressure equalization. Compared with conventional porous PTFE membrane solutions, DIAvent® is more robust and significantly increases the operational reliability of the battery units.

Housing, housing edges and housing covers – Elastomers

Both the outer shell and the interior of high-tech battery systems must reliably prevent the ingress of

dust particles and liquids under all operating conditions. At the same time, the system must effectively damp vibrations and mechanical shocks. High-quality elastomer seals and damping elements (in the PU and silicone material classes) ensure reliable sealing of the battery housing over the battery's entire service life. The types of seals required here include press-in seals, foldable composite seals and so-called XL edge-bonded seals. In these applications, the elastomers combine long-term flexibility with optimized thermal and safety management for the robotic battery.

Heat protection mat/heat shield – Thermoplastics

See above

Rotary drive units – Power transmission via joint function

Swivel and rotary drives generate maximum torque within extremely limited installation space and release it across a wide range of swivel angles in swivel and rotary actions. Angles are usually specified within the range of 45° to 360° in robotics applications. These drives are compact assemblies that move a drive shaft through hydraulic or pneumatic pressure. In cobots, rotary drives are required for functions such as tool or workpiece changes. In humanoid robots, they primarily enable turning and holding functions. Reliable motion control and stabilization require the following sealing and damping solutions::

For outdoor use – IPSR®

IPSR, the abbreviation of Ingress Protection Seals for Robots, provide excellent protection against environmental influences with minimal friction, particularly in outdoor applications. With their high-quality polyurethane materials and application-specific sealing geometries, these seals and damping elements are designed for a long service life. Low friction, high flexibility, and easy installation ensure reliable sealing performance, increasing the long-term functionality and process efficiency of articulated robots and humanoids.

O-Ring – NBR

O-rings made of NBR function as double-acting sealing elements. The compression resulting from an installation in an axial or radial direction creates the initial sealing force in the system. The system pressure then reinforces this preload, increasing the overall sealing force as the system pressure rises. Under pressure, the O-ring behaves similarly to a fluid with high surface tension and distributes the pressure evenly in all directions. Manufacturers use the NBR material class in such cases primarily for its excellent resistance to oils and other lubricants.

Radial shaft seal – NBR / FKM

Radial shaft seals form the interface between rotating and stationary components. They keep lubricants inside the machine while preventing the ingress of contaminants. Each seal has a precisely shaped sealing lip that maintains continuous contact with the rotating shaft. In cobot applications in particular, rotary drive components are subject to extreme loads – such as high acceleration, abrupt braking and continuous rotational movements. In these process chains, low friction plays a decisive role in the robot's reliability and service life. Oil seal materials and NBR / FKM-based radial seals minimize wear at the lip-shaft interface and maintain stable contact pressure even at varying speeds and temperatures.

Drive shaft seal – NBR / FKM

Drive shafts are designed to effectively transmit rotational motion and torque from one shaft to another – in other words, for torque transmission between offset drive axles. The same applies to the sealing profiles and materials required here as for the radial shaft seals described above.

Grease Wafer Seals – PTFEE

PTFE offers high thermal stability and excellent flexibility across a wide temperature range. In robotics applications, VMQ is used where temperature fluctuations are associated with maximum physiological performance and where weather exposure, ozone, and UV radiation may dominate the work environment. These outstanding material properties are complemented by excellent electrical insulating properties and good resistance to a wide range of polar chemicals.

Linear drive units – Motion with highly precise fine adjustment

Linear drives convert electrical energy directly into linear motion and enable robots to accurately perform a wide range of tasks – with precision, efficiency and repeatability. This makes them essential for modern robotics applications. In humanoid robots, linear drives control joints and limbs with human-like dynamics and natural joint movements. Cobots also benefit from their compact design, especially in confined production environments, and operate safely and reliably in human-machine collaborations – even under challenging environmental conditions. The following sealing and damping components are required in these applications:

Piston seal – PU

Piston seals provide reliable sealing between the piston and the cylinder tube of the robotics application. They must maintain their sealing function even under extreme conditions, such as high pressures, strong temperature fluctuations and potential chemical influences from the surrounding environment. In addition to offering high wear resistance, the seal contributes to durable force transmission through its smooth, low-friction sliding along the mating surface. Depending on the operating environment of the cobot or humanoid, the materials used for piston seals are primarily polyurethane and polyamides, with sealing geometries manufactured to precise specifications. This allows them to minimize abrasion of the contact surfaces and ensure lower dynamic friction.

Contamination ring seal – NBR, FKM

Preventing leakage or unintended media transfer is crucial for the safe operation of linear drive units: If there is a lack of lubricant inside the system, failures will occur over time. Conversely, if lubricants or wear particles escape from the robotic system in medical technology applications, they may cause hazardous contamination of the operating environment. Compression seals made of NBR or FKM are used to address these demanding requirements. These offer high resistance to aging, excellent resistance to lubricants and low compression set.

Rod seals and sliding seals – PU

Rod seals reliably keep the operating medium of the linear drive system within the cylinder and prevent the ingress of dirt, moisture or dust particles. Even under high system pressures, strong dynamic loads and extreme environmental conditions, these seals ensure maximum functional reliability, thus guaranteeing the operational capability of the robotics application. With different seal designs, they also ensure that any remaining oil film on the piston rod is kept to a minimum. For rod seals as well, PU has proven to be the preferred material. This is due to its high media resistance and its mechanical load-bearing capacity, its excellent elasticity and outstanding resistance to tearing and abrasion.

Damping elements/hydraulic shock absorbers – PTFE, NRR

In linear drive systems, mechanical or electronic cams convert rotational motion into linear motion with high precision and acceleration. The damping elements required for these systems protect the sensitive joint mechanisms from vibration transmission and reliably absorb even strong shocks. They are made from the robust, durable and rubberized elastic PTFE material class. Depending on the requirements profile, damping elements made of natural rubber (NR) also prove effective here.

Hand assemblies – Sensors and precision

The development and construction of functional hand assemblies represent a core discipline of humanoid robotics. Robot hands are interfaces for interactions. They must be able to coordinate complex movements. They must apply different gripping techniques and respond to external stimuli in such a way that the applied force precisely matches the task at hand. This requires small motors, sophisticated sensor systems and perfectly trained control algorithms. For this highly complex drive technology, many of the sealing components described in the previous sections are required in small-scale formats. However, one decisive area for materials experts has not yet been addressed: tactile sensing:

Sensitive fingertips – conductive polymers

So-called tactile sensing encompasses touch perception and manipulation by robotic hands and, going forward, is intended to approximate the human sense of touch. Various conductive sensor materials are currently being researched. In June 2025, the University of Cambridge announced the development of an electronic polymer skin designed to provide robots and prosthetic devices with near-human tactile perception. This skin is based on conductive carbon nanotubes, which in turn enable robots to interact safely with their environment. Initial elements of tactile sensing are also being developed and tested within the sealing industry, with conductive polymers forming the basis for these pioneering developments.

Sliding seal – see linear drive units, „Rod seals and sliding seal rings”

WEBSITE

IPSR® seal – see rotary drive units “For outdoor use”

WEBSITE

In a nutshell: Is there an overview of applications, materials, sealing and damping designs for humanoid robots applications?

There is now – because a picture is worth a thousand words. We have compiled all the information listed above into three diagrams. So, you can immediately see, which materials and designs are suitable for achieving optimum peak performance. Figure 1 shows a humanoid robot in which all areas requiring sealing and damping elements or sensor modules are marked in blue. The illustration extends from the head (sensor hub with cameras, LIDAR, IMU, calibrated proximity sensors, and radar) through the shoulder joints with actuators and the tactile elements in the hand area, all the way down to the rotational joints at the knees and the rubberized foot pedals. Figure 2 zooms in on the areas marked in blue.

The numbered circles in figure 1 are clickable and link to an overview on the following pages. The individual components are shown here along with their corresponding material classes. This overview is designed to help you find the right highly specialized sealing and damping solutions. For individual inquiries, you are welcome to contact the specialists at Freudenberg Sealing Technologies, for example.

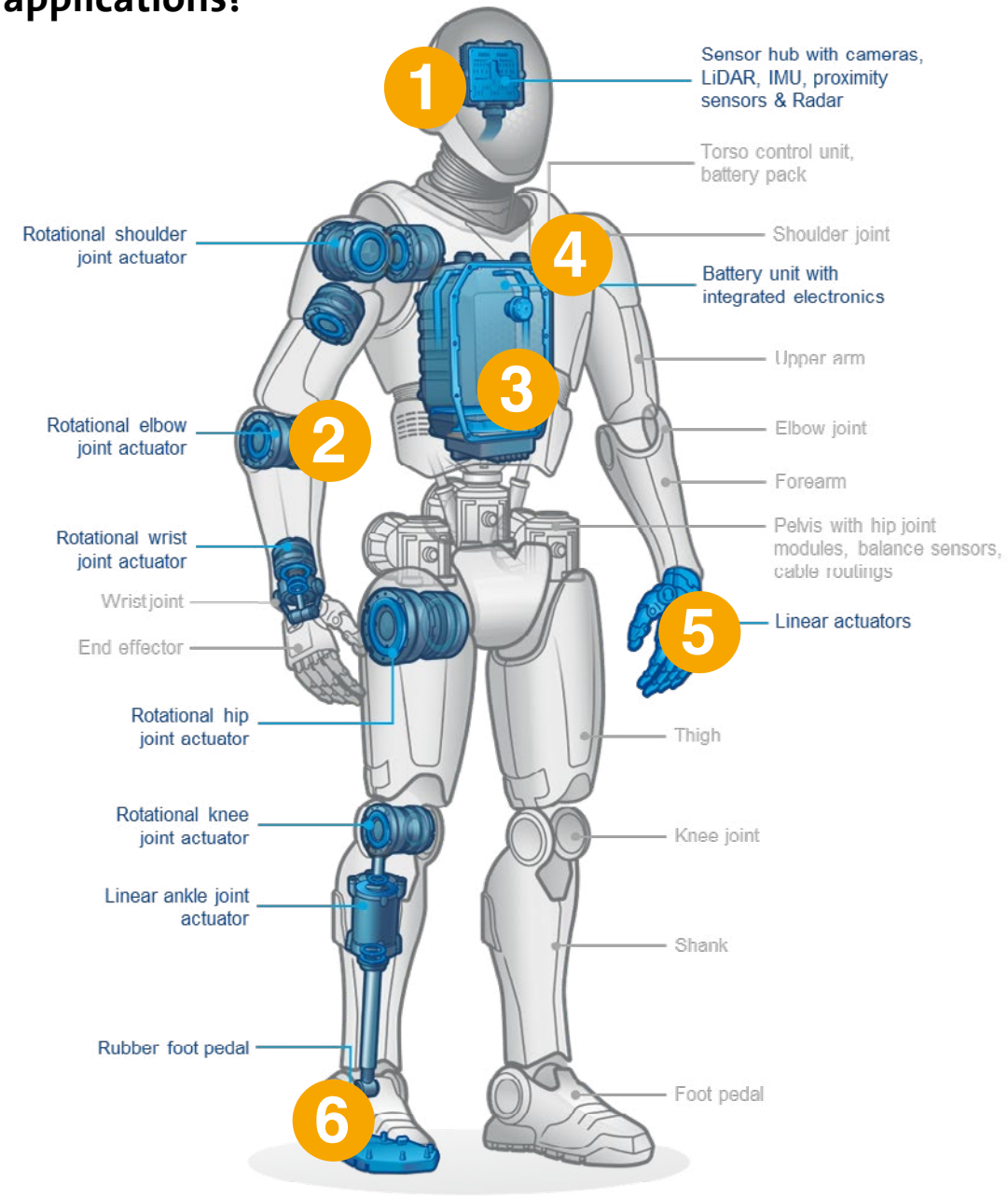
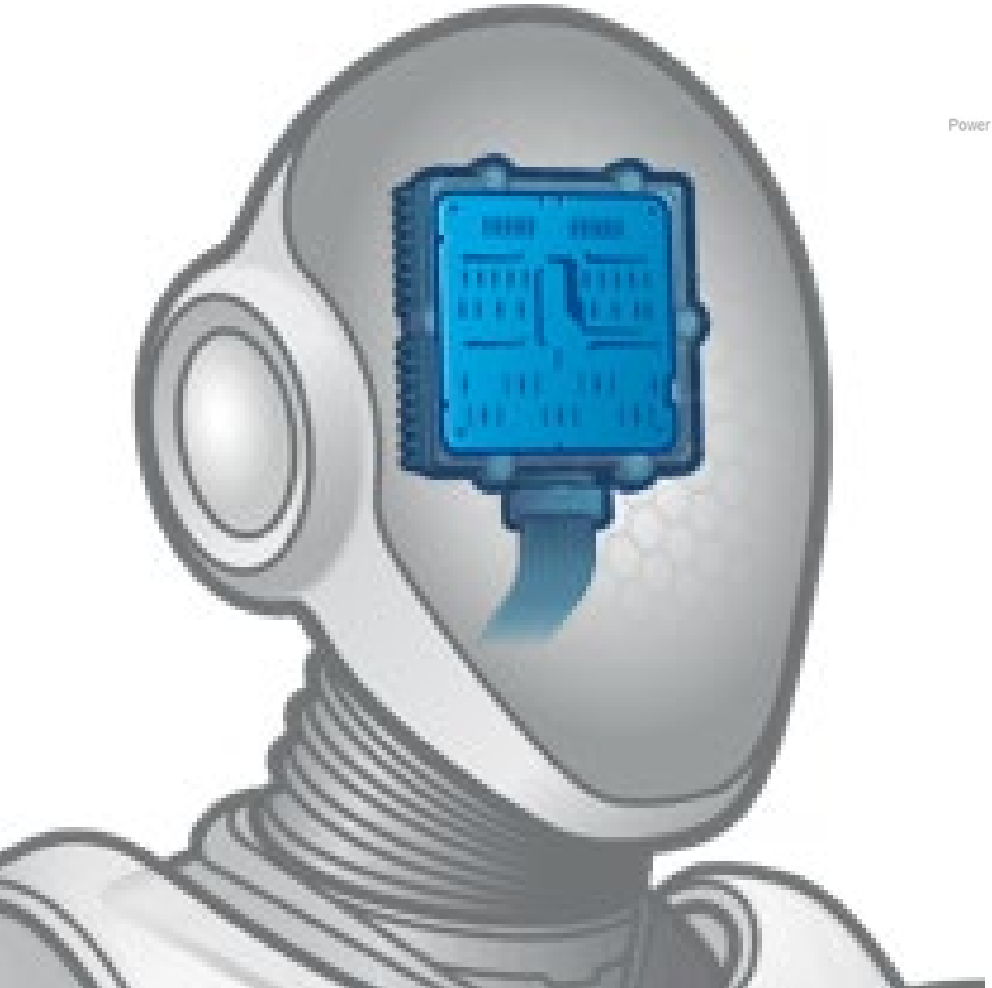
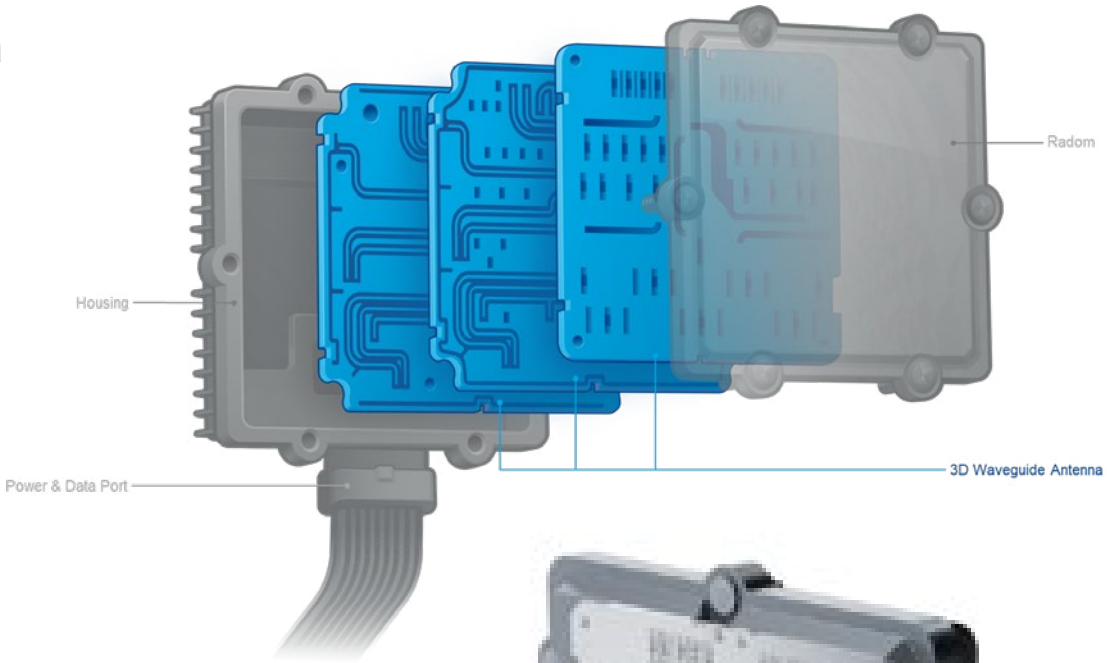


Fig. 1: Applications for Seals and Damping Elements in Humanoid Robots

1 3D Sensing - Waveguide Antenna

For the sensing hub inside the headgear





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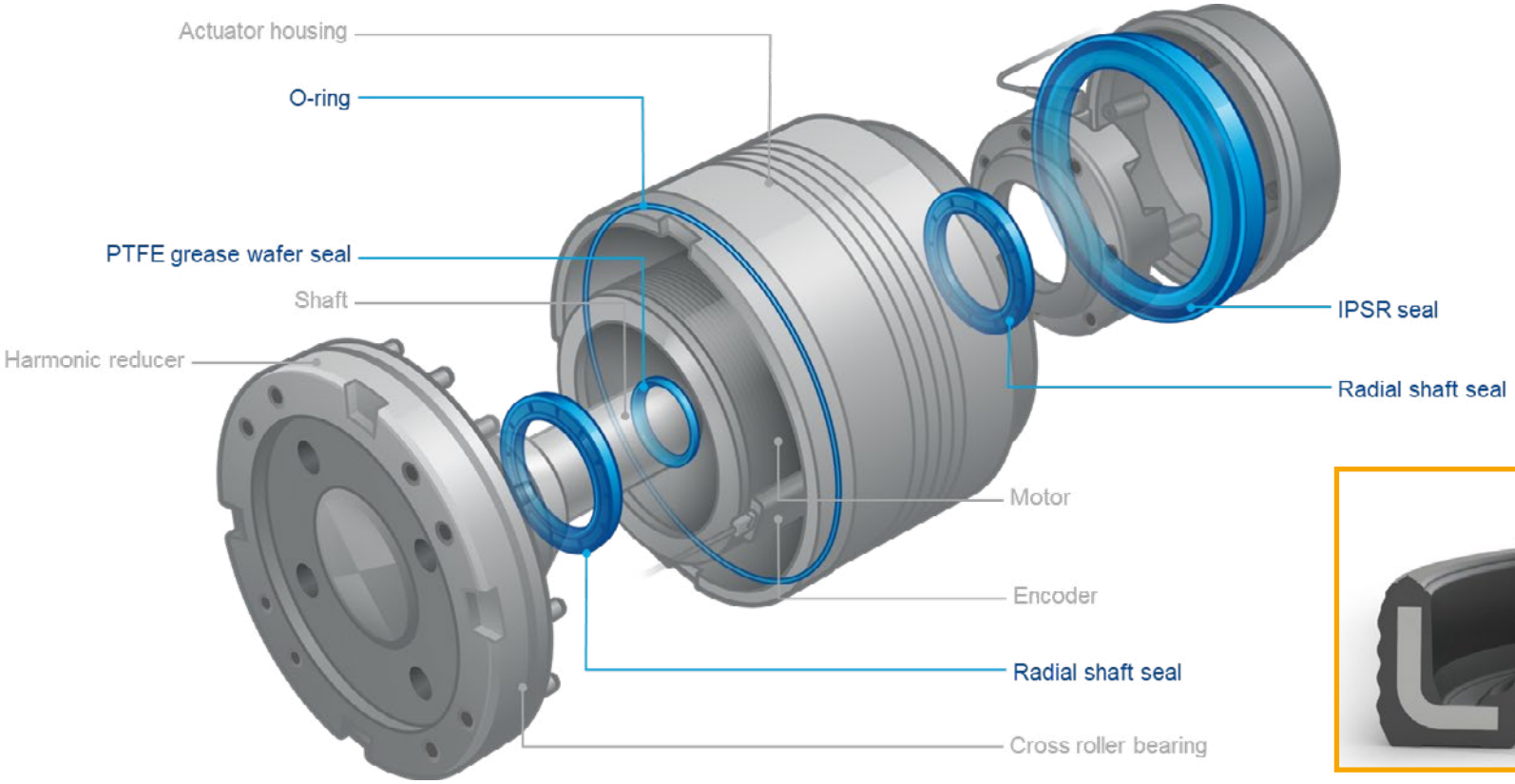
2 Long-Life Sinus Seals

PSS
Applied in gearboxes / motors for humanoids



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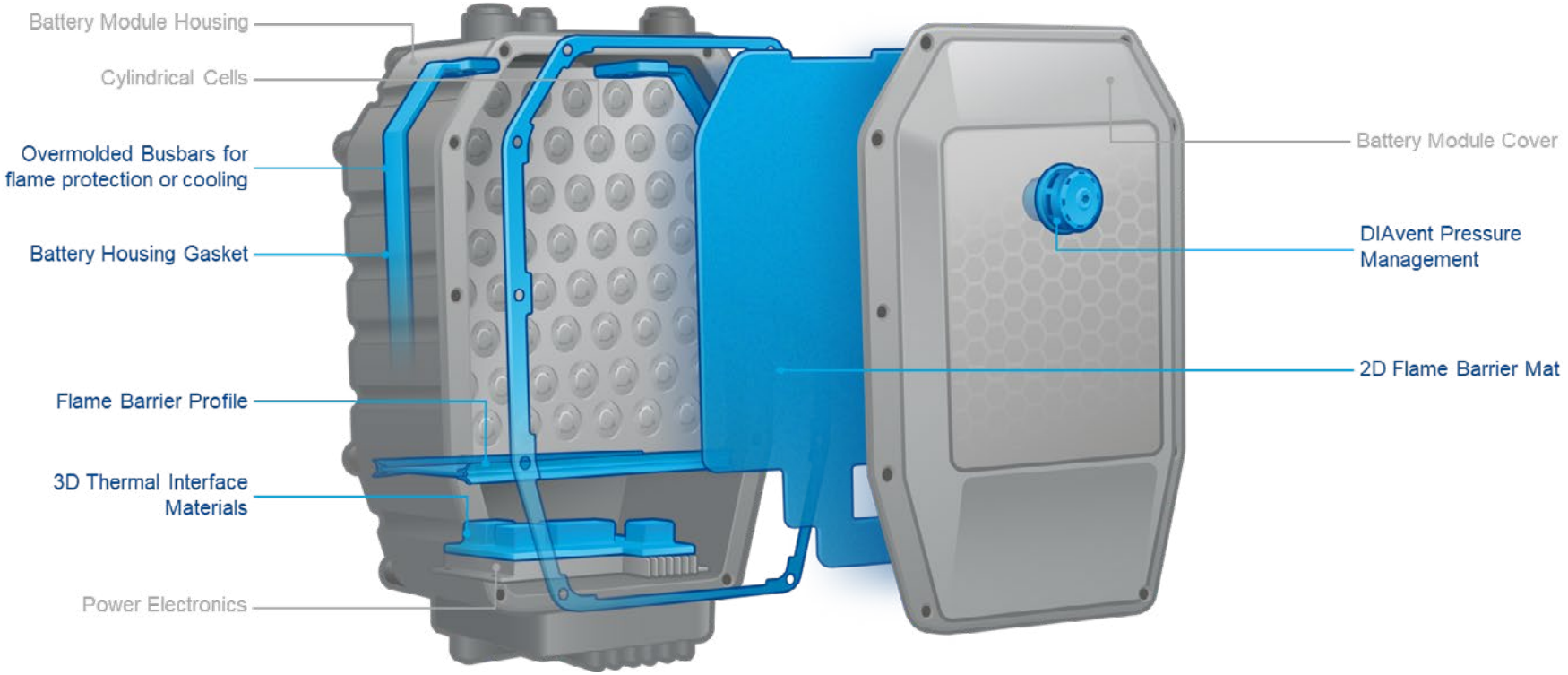
3

Ventilations

DiaVent Min
for battery cells

Gas-tight Busbars

Busbar Sealings
for battery cells



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4 Compact Design

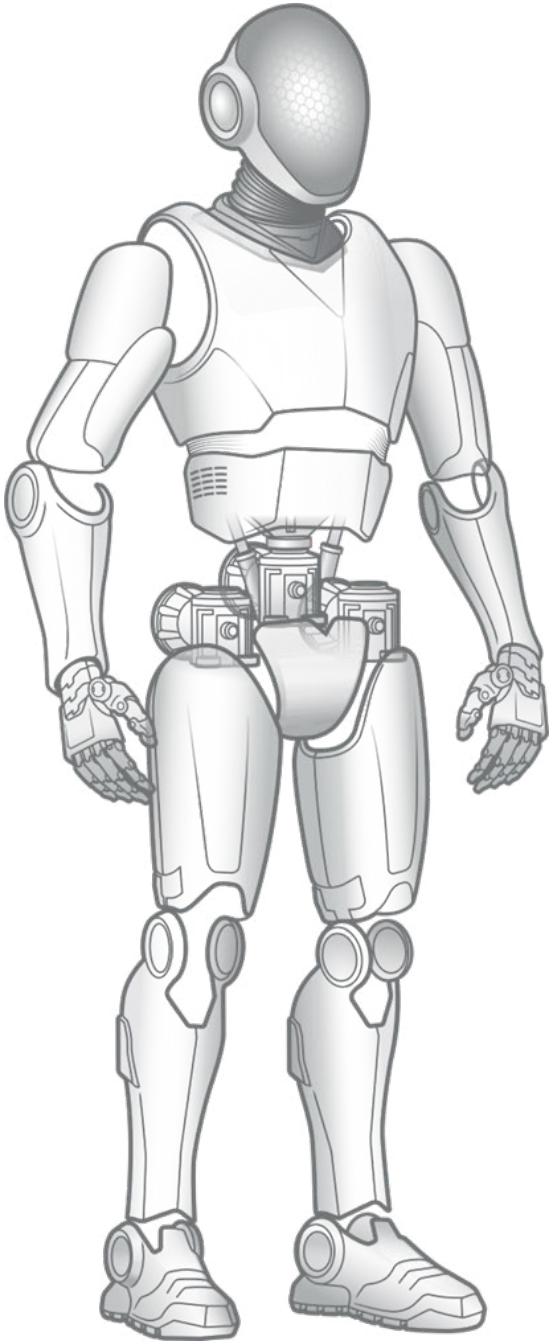
PTFE Wafer Seals
Secure internal lubrication in humanoids

4 Body Covers

Rubbers Gaskets
For robot body covers / flanges

4 Hygienic Design

Hygienic USIT
For robot body covers / flange



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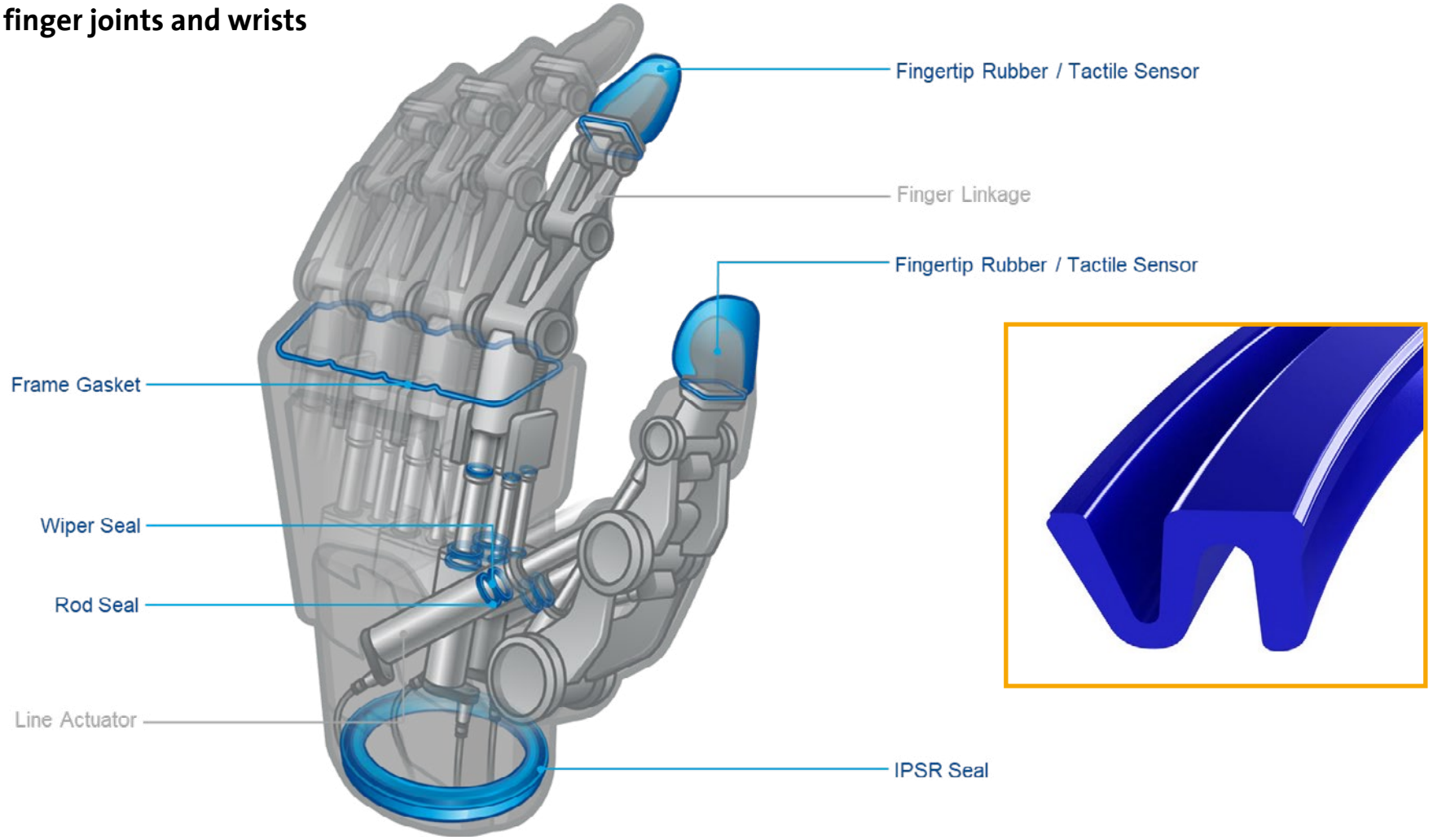
5 Waterproof – ISPR

For finger joints and wrists



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6 Transmission

PU Wheels
For AGVs and
wheeled humanoids

zurück zur Übersicht

Which standards and regulations are relevant for robotic systems?

Robotics systems are subject to many regional and globally interconnected guidelines and standards that relate to sealing and damping technologies. These define a comprehensive regulatory framework for the new development and operation of robotics applications. This means that development teams and integrators must continuously stay on the ball and follow legal requirements when they incorporate the latest technological advances into their designs. Here is an excerpt of the guidelines and standards that were current at the time this white paper was written. For the development of new robotics projects, we strongly recommend delving deeper into this topic.

ANSI/RIA R15.06-2012
American National Standards Institute (ANSI) standard for industrial robots and robotic systems; defines requirements and guidelines for the inherently safe design, safeguards and information for the use of industrial robots

WEBSITE

ATEX-Richtlinie 2014/34/EU –
Directive governing equipment and protective systems intended for use in potentially explosive atmospheres

WEBSITE

China's Industrial and Military Robotics Development; Ministry of Industry and Information Technology (MIIT), National Development and Reform Commission (NDRC)
Guideline. This is aimed at establishing a complete robotics industry system in China, including the expansion of industrial production capacities and promotion of innovation and technological development

WEBSITE

IS 15033 (2001)
Manipulating Industrial Robots – Indian national standard based on international norms; defines performance criteria and test methods for industrial robots

WEBSITE

ISO 8373:2021 (en)
Robotics, Vocabulary; defines terminology used in standards and regulations related to robotics

WEBSITE

ISO 10218-1:2025-02
Robotics, safety requirements – Part 1: Industrial robots; regulates requirements for the design of industrial robots and the integration of their applications

WEBSITE

ISO 10218-2:2025-02
Robotics, safety requirements for robot systems in industrial environments – Part 2: Robot systems, robot applications, and integration of robot cellsn

WEBSITE

DIN EN ISO 10218-2:2021-03
draft: Robotics – safety requirements for robot systems in industrial environments, part 2: Robot systems: Robot applications and integration of robot cellsv

WEBSITE

DIN EN ISO 13482:2024-10
Draft: Robotics – Safety requirements for service robots (ISO/DIS 13482:2024); German and English version prEN ISO 13482:2024

WEBSITE

DIN EN ISO 13849-1:2023-12
Safety of machinery; rules specifically applicable to robotics for safety-related parts of control systems and general design principlese

WEBSITE

ISO/TS 15066:2016
Safety requirements for collaborative industrial robot systems and their working environments; supplements the requirements and guidelines for the operation of collaborative industrial robots according to ISO 10218-1 and ISO 10218-2

WEBSITE

ISO 18646-1:2016-09
Robotics, performance criteria and related test methods for service robots – Part 1: Locomotion of wheel-driven robotsn

WEBSITE

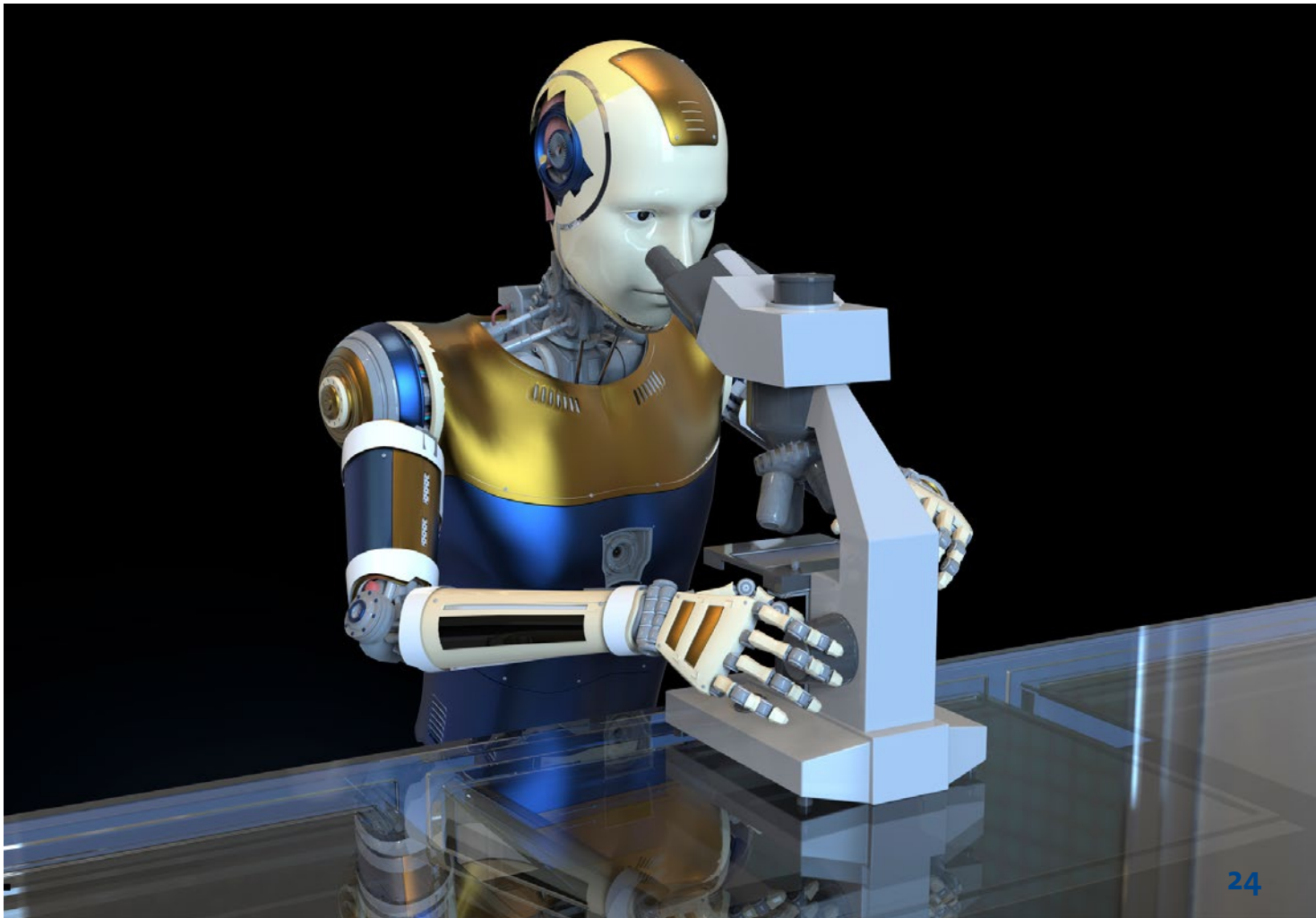
JIS Y1001 (2019)
Japanese Requirements for Safety Management Systems for Robot Services / Using Service Robots; new JIS standard defines requirements for safety management systems for robot services and service robots

WEBSITE

Schutzarten IP54 und IP65
VDI 2740 Blatt 1:1995-04

VDI 2740 Sheet 1:1995-04 – Mechanical equipment in automation technology, grippers for handling devices and industrial robots

WEBSITE



Question for the industry experts: Are there new manufacturing or testing methods for seals and dampers in the field of cobots and humanoids, Dr. Daniel Froelich and Christian Wilbs?

Dr. Daniel Froelich, Technical Director, Lead Center Simmerring at Freudenberg Sealing Technologies, says: “A key factor for success in robotics is the combination of a high-performance product portfolio, a deep understanding of applications, and the ability to quickly bring innovative solutions into series production. Freudenberg Sealing Technologies has a product and material portfolio for radial shaft seals in industrial robots that has been built up over decades and continuously refined. On this basis, we have established a leading market position in the field of rotary seals for robotic applications.

A particular challenge lies in the highly dynamic swivel movements found in modern robotic systems. Under these conditions, our innovative seal designs achieve high flow rates and are combined with high-performance elastomer materials that are specifically tailored to the synthetic lubricants used in robotics.

Just as important as the product itself is the application expertise we have built up over many years. Successful sealing solutions for robotics applications require a deep understanding of the entire system’s requirements — from the lubricants used and highly dynamic load cycles to the specific environmental conditions. This expertise enables us to work with our customers to develop robust and high-performance sealing systems.”

Christian Wilbs, Product Design Engineer at Freudenberg Sealing Technologies, says: “Today, modern sealing solutions perform significantly more tasks than simply sealing. Through modifications that have virtually no impact on installation space, additional functions can be integrated that create real added value for the user. The spectrum ranges from simple dust lips to applied nonwoven washers and integrated PTFE washers. In addition to protecting against dust, dirt, and water, such solutions can, for example, also dissipate electrical voltages, thereby providing additional protection for rolling bearings.

While robotics applications in the past focused primarily on 6-axis robots, Delta robots, SCARA robots, and cobots, a new generation of systems is currently gaining importance: humanoid robots. Many of the requirements for dynamic seals are similar to those of classic industrial robots. At the same time, new challenges are emerging. These include, in particular, very small installation spaces, significantly shorter development cycles, and collaboration with new market participants who are often characterized by a distinct startup mentality.

This is precisely where we see our particular strength. With our innovative sinus lip seal portfolio, we have a clear USP for highly dynamic applications. This is complemented by a state-of-the-art test facility, global production sites, and extensive experience from numerous successfully completed projects in the field of conventional industrial robots. This combination puts us in the ideal position to reliably and efficiently meet the requirements of future generations of robots as well.”

Dr. Daniel Froelich Christian Wilbs

Where can I get industry news in the robotics sector?

Every day, new portals and information hubs emerge all over the world that report on innovative trends and inspiring success stories in robotics. At the same time, conferences and leading trade fairs offer specialists opportunities to present product innovations and discuss ideas and concepts. Here we provide you with a selection of tips that either provide timely coverage of robotics developments or exert influence across the entire industry. With this list, we encourage you to delve deeper into the various information channels.

AUTOMATE
largest automation trade fair in North America

WEBSITE

ChinaRobotNews
Portal für Aktuelle Nachrichten und umfassende Analysen zur Robotik- und KI-Branche in China, inklusive neuesten Technologieentwicklungen und Fertigungsverfahren

WEBSITE

Deutscher Robotik Verband e.V., c/o Hochschule Trier
Portal for up-to-date news and comprehensive analyses on the robotics and AI industry in China, including the latest technology developments and manufacturing processese

WEBSITE

GTAI (Germany Trade & Invest)
Official platform for Germany's robotics industry; reports on industrial robotics developments and market trends

WEBSITE

Humanoid Robotics Technology (International/ Europa)
Specialized portal for humanoid robot developments; annual rankings of the top humanoids worldwide

WEBSITE

IEEE Spectrum, Robotics Section (International/ Europa)
IEEE's leading technical magazine with a dedicated robotics section; comprehensive reporting on industrial robots, humanoid robots and AI integration

WEBSITE

IFR Federation of Robotics
Industry portal of the World Robotics Federation; robotics statistics and trends, reports on global robot installations, industrial robots and humanoid developments

WEBSITE

Industrie 4.0 im internationalen Kontext
Core concepts, results, trends; the book Industry 4.0 in a Global Context presents the most important components and essential aspects of the overarching concept of "computerization of the value chain" in various contributions by renowned authors

WEBSITE

Robotics India News & Updates in 2025
Published by AIM; the world's largest media, research and events organization focused exclusively on developments in the field of artificial intelligence

WEBSITE

The Robot Report (USA)
Comprehensive reporting on global robotics markets including China and India

WEBSITE

TQ – Future Markets Magazine
Booming robot market

WEBSITE

A checklist: What information do I need to select seals and dampers for various robotics systems?

To help save time when selecting the ideal materials, sealing and damping designs for individual robotics development processes, here is an alphabetically sorted selection of checkpoints that you should take into account. This list is intended solely as an aid for starting your research.

Pressure conditions and pressure peaks:

- ☐ What is the static and dynamic operating pressure? ?
- ☐ Do pressure surges occur as a result of rapid valve switching or emergency shutdowns that temporarily exceed nominal pressure values?

Installation space restrictions: :

- ☐ What axial and radial installation dimensions are available?
- ☐ Are there restrictions due to adjacent components, cable routing or sensor systems that require special geometries?

Electrostatic properties:

- ☐ Is electrical conductivity required to prevent electrostatic charging or is the opposite – an insulating effect – required? ?

Kinematic load profiles:

- ☐ What movement frequencies, acceleration values and travel speeds occur at the contact point?

Contamination level of the operating environment:

- ☐ Are dust particles, metal abrasion, spray water or aggressive aerosols to be expected??

Service life expectations and maintenance intervals:

- ☐ What operating hours or load cycle counts must seals and damping elements achieve?
- ☐ Are maintenance intervals planned for scheduled replacement or is maintenance-free operation required?

Media compatibility and chemical resistance:

- ☐ Which fluids, lubricants, hydraulic oils or cleaning chemicals come into contact with the seal/damper?

Emergency running properties in the event of lubricant loss:

- ☐ How does the seal behave in the event of a temporary loss of lubrication?
- ☐ Is a dry-running tolerance required for safety functions?

Surface quality and tolerances of the contact surfaces:

- ☐ What roughness values and geometric tolerances apply to the shaft and housing bores?

Frictional torque and energy efficiency:

- ☐ What maximum frictional torque can be tolerated without affecting the drive design?

Temperature range in the operating cycle:

- ☐ What are the minimum and maximum temperatures and temperature gradients?

Approvals and conformity to standards:

- ☐ Which industry-specific certifications are required?
- ☐ Which documentation obligations must be observed?

Conclusion

The rapid and multifaceted development of robotics now encompasses all process chains in the manufacturing industry. Research institutions, spin-off companies, and globally active, cross-industry technology leaders act as key drivers of these innovation boosts. In this dynamic market environment, highly elastic and durable materials, sealing profiles and sophisticated damping designs ensure that mechanical excellence, intelligent sensor systems, and AI-based control algorithms translate into highly precise movements. In this booming environment, however, one constant will likely continue to prove itself in the years to come: The greatest innovations emerge from a smart idea that arises from dialog.

In this context, we would like to draw your attention to a product group that originated in the automotive industry and is currently being tested for transfer into humanoid robotics: delicate waveguide antennas for radar sensor systems. These electrically highly conductive hollow waveguide antennas transmit and receive electromagnetic signals with minimal loss when they are reflected by an object. To achieve this waveguiding capability, manufacturers metallize fine channel structures using application-specific coating processes. This manufacturing approach enables a high degree of design freedom, which is increasingly requested by sensor manufacturers in major markets across Europe, the United States and East Asia.

We look forward to seeing which cross-industry key technologies will ultimately prevail and welcome your feedback as we continue to develop this white paper.

Glossary – Material classes and brand names

ACM	Acrylic rubber
AEM	Acrylate-ethylene rubber
Busbar	Essential for Power Distribution
DIAvent	Pressure valve; IP classes IPX7, IPX8, IP6X, IPXXD, IPX9K,
eCON	Electrically Conductive Nonwoven Component for Safe Grounding
EPDM	Ethylene propylene diene rubber
FKM	Fluoro rubber
HNBR	Hydrogenated acrylonitrile butadiene rubber
IPSR®	Ingress protection seal for robots
NBR	Nitrile butadiene rubber
NR	Natural rubber
O-Ring	Standardized ring-shaped sealing element
Quantum®	PTFE linear drive wedge bearing assembly
PTFE	Polytetrafluoroethylene
PU	Polyurethane
Simmerring®	Standardized shaft seal for axial or radial shafts
TPE	Thermoplastic elastomers
VMQ	Vinyl-methyl-silicone-rubber
Waveguide Antenna	Key Component of a Radar Sensor

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