[New Product]

Lightweight Bearing for Robot

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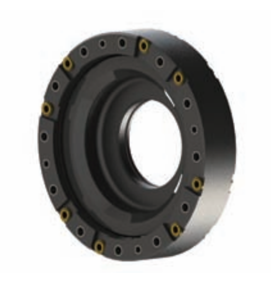

Robotic arms do have many qualities, but intelligence is not their best point. It is necessary and important to be programmed move by move. They work in a XYZ coordinates world associated to θ_X θ_Y θ_Z for rotations. Moreover, programming and maintenance are matter for specialists. Their size and potential tremendous force imply large secured areas and heavy procedures when an incident occurs.
Some trends can be found such as Cobotics that have new technologies of motion control and can coexist with surrounding humans.
Based on its know-how, experience and Market understanding, **NTN-SNR** prototyped a bearing concept that aims to accompany the Robotics Megatrends. Making the bearing lighter, less expensive by tuning its stiffness according to real needs of coming technologies.

1. Introduction

Many characteristics are required for industrial robotic arms; however, the following two points are particularly important:

- Robot arm design must conform to the demand for several sizes and use in a broad range of applications while also considering the cost of the robot arm.
- Higher functionality of robot arms and improved operability

To satisfy these requirements, particularly from a functionality standpoint, robot arms use technology to determine various conditions in addition to high rigidity, broad operational range and easy operation. Therefore, bearings supporting the robot arms are required to be designed to conform to these technology trends.

In this paper, we briefly discuss industrial robots and present the lightweight bearings for robots developed by **NTN-SNR**.

2. Structure and capability of robots

The basic functionalities of today's industrial robots have evolved first from positioning, then to grabbing objects with "hands" to more detailed tasks such as assembling, welding, painting, etc. which previously was the work of humans. For example, in the assembly process, when parts are conveyed by robots, the robots have to grab the parts in the same way and transport them to the predefined locations following the same trajectory every time. Therefore, the positioning of the robot and objects must always be accurate. This is true with welding and painting processes as well, so accurate positioning and stable operation is again required.

Fig. 1 shows a typical perpendicular articulated 6-axis robot for industrial use. The programming for operation is achieved by expressing and modeling the accurate motion of the robots in X, Y, Z and θ_X, θ_Y, θ_Z axes, as shown in **Fig. 2**, for each process to be accomplished.

Therefore, good performance of today's industrial robot arms is determined by the following items:

- Accuracy of positioning
- Accuracy of positioning reproducibility
- Rigidity

With the performance of these items, motions are combined to establish automatic operation of an industrial robot. In addition, sufficient rigidity to support the payload capacity of the robot is required.

Fig. 3 shows the performance required for the current industrial robots. Today bearings for industrial robots are heavy due to the necessary control of axis, high precision, high rotational speed (acceleration) and high rigidity required.

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Fig. 4 shows an image of the industrial robot line-up. In general, the maximum payload capacity is approx. 1,500 kg, however, the majority of applications are 20 kg or less. High rigidity is required not only for maintaining accuracy of positioning, as mentioned earlier, but also for supporting the weight of the manipulator.

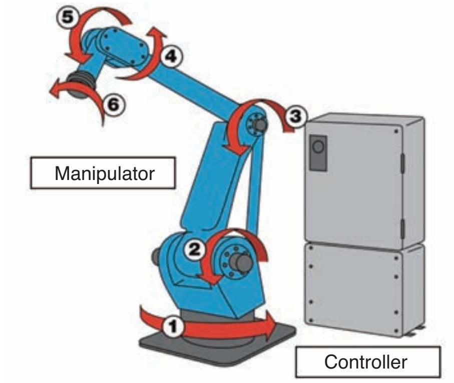


Fig. 1 6 axis robot (manipurator and controller)

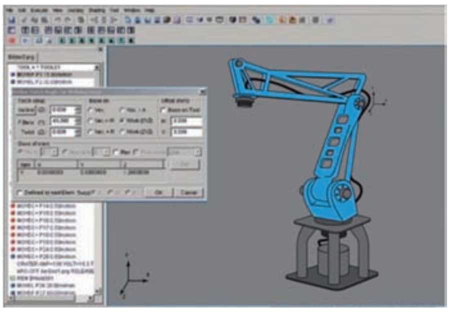


Fig. 2 Modelling and programing for motion

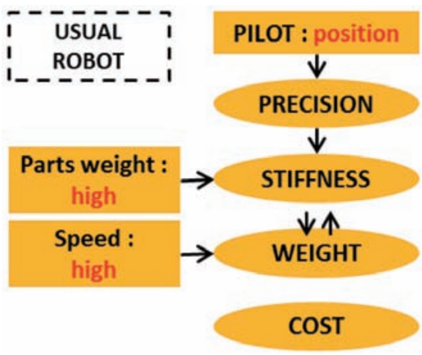


Fig. 3 Specification of usual robots

3. Cobotics and new technology

3.1 Cobotics

Cobotics derived from "cobot", an abbreviation of collaborative robot, means a collaborative robot that operates in an environment surrounded by humans. Fig. 5 shows examples of operation. Cobots detect the co-working humans and other robots when they approach the cobots and work on their own without making contact with others. Cobots also work for automated or assisted driving of vehicles. For example, they can sense how humans work and assist them with their work or change their behavior accordingly.

The payload of cobots is usually 20 kg or less and these robots are becoming lighter and smaller. However, these approaches are being adopted by large units, as well.

Example of autonomous cobot

Example of cobot to follow man's movements while multiplying its strength

Fig. 5 Payload of industrial robots

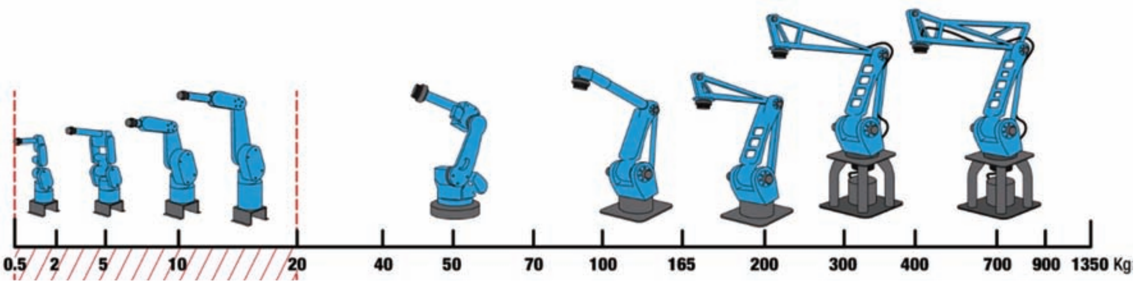


Fig. 4 Payload of industrial robots

The cobots are mainly deployed for tasks with less added value, time consuming tasks and repetitive tasks of critical process. Cobots are also aimed at reducing the load of workers and preventing injuries such as arthritis.

3.2 New technologies

Among the technologies on robots, the following are directly related to control:

- Image processing technology
- Force sensing technology
- Laser measurement technology

Fig. 6 shows some examples of movement using the above technologies. These technologies enable robots to understand the shape of the work, support it, and accurately transport it after computational processing for various movements.

They also assist operation with other robots and adjust distance with the workers in the proximity.

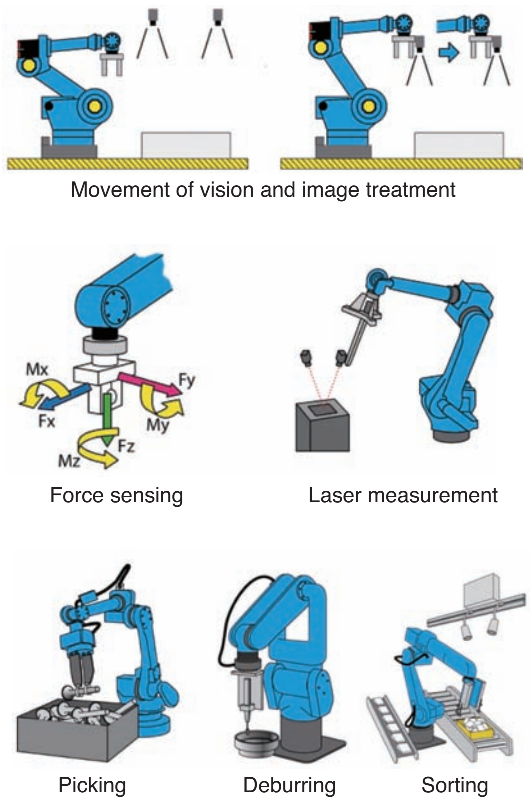


Fig. 6 Example of movement by new technologies

4. Bearings for robots developed by NTN-SNR

In Europe, **NTN-SNR** is a leading bearing manufacturer of reducers for robots and maintains a high share not only for industrial robots but also for work/motion-assist robots.

Fig. 7 shows an example of the specifications for the manipulator and bearings of common industrial robots. The rigidity required for the bottom most turning bearings and the wrist rotating bearings at the tip of the arm are significantly different even for the same robot. Therefore, the bearings to be used in the robot must be individually selected depending on the task, payload, position and operation of the robot.

Due to the above reason, crossed roller bearings shown in **Fig. 8** or four-point contact ball bearings are used for turning, rotating and oscillating robot joints and the bottom most bearings need to support the weight of the manipulator.

NTN-SNR focused on developing a more lightweight bearing while maintaining the previously mentioned functional requirements.

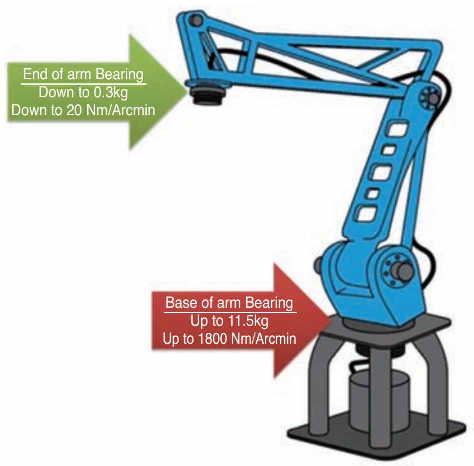


Fig. 7 Manipulator and specification example of bearing

Fig. 8 **NTN-SNR** crossed roller bearing

5. Lightweight bearings for robots

The design concept of **NTN-SNR** lightweight bearings for robots is a composite material of resin and steel. Conventionally, inner and outer rings are specially shaped and made of steel because they are attached to the peripheral components with bolts, etc., however, the developed product uses steel only for bearing raceway assembly and rolling elements and adopts resin for the specially shaped part to be attached to the peripheral components.

The application of resin must function without affecting the bearing peripheral components. Therefore, we also considered the operating environment of industrial robots in the selection of resin material and adopted nylon resin of high-melting point with excellent strength.

Also, the developed bearings can replace the conventional bearings without redesigning of robot joints and reducers.

In the following, we present the types of lightweight bearings for robots.

5.1 Non-separable type

With the non-separable type, resin is injection molded on the inner and outer rings of the deep groove ball bearings, as shown in **Fig. 9**. The rigidity is increased by reducing the internal clearance of the bearings.

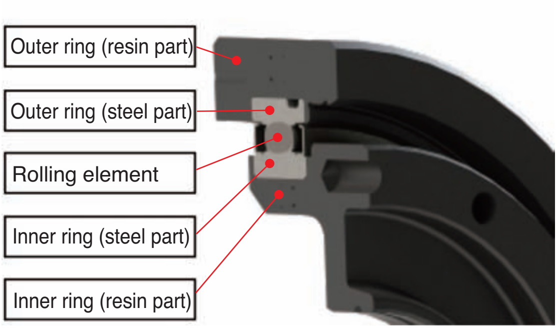


Fig. 9 Lightweight bearing for robot (non-separate type)

5.2 Separable type

The separable type is the crossed roller bearings shown in **Fig. 10**, to obtain higher rigidity than the non-separable type which adopted deep groove ball bearings. In the assembly of the bearings, only the inner ring is molded in a single piece with resin and the resin parts of the outer rings are assembled from both sides of the steel parts after the rollers are inserted.

Also, as shown in **Fig. 11**, the widths of the separable resin parts on each side are different. The reason is that the outer rings made of steel are engaged only to one side of the resin parts, so that no displacement on the outer ring raceway of both sides is created in the radial direction.

There are several ways to connect both sides of the resin parts, such as use of rivets as shown in **Fig. 12** ①, or to insert steel-made sleeves and fixed by bolts as shown in ②.

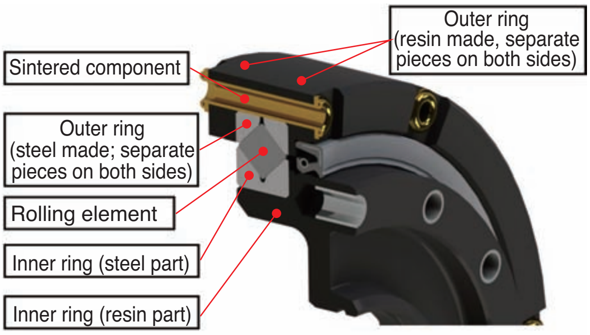


Fig. 10 Lightweight bearing for robot (separate type)

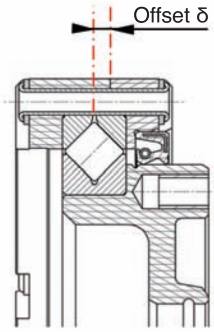


Fig. 11 Assemble example of lightweight bearing (separate type)

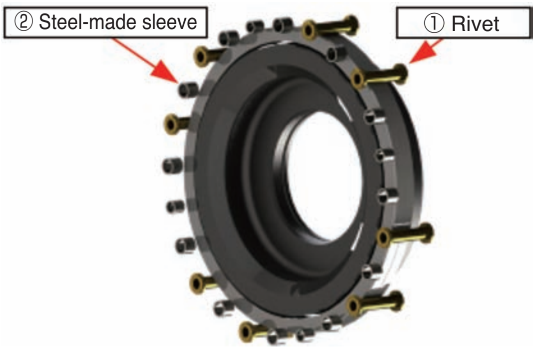


Fig. 12 Fastening example of lightweight bearing

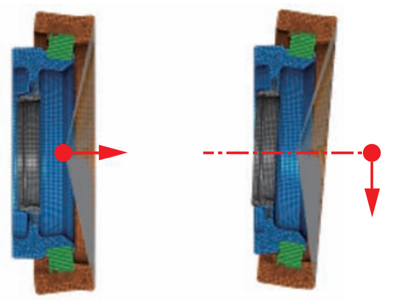
5.3 Rigidity

The developed bearings have reduced rigidity compared with the conventional bearings because the specially shaped part of the inner/outer rings is replaced with resin. **Table 1** and **Fig. 13** show an example of the comparison of rigidity of the separable type (crossed roller bearings) by FEM analysis.

In case of cobotics discussed in Section 3, which are controlled by image processing and force sensors, the high speed and high rigidity requirements of current robots are not required; therefore, this reduction of rigidity of the developed product should be in the permissible range.

Table 1 FEM Analysis to compare the stiffness between developed bearing and current bearing

		Current bearings	**Developed bearings**
Bearing main sizes mm		ϕ40×ϕ110×26	
Analysis conditions	① Axial load kN	40	
	② Moment load Nm	1000	
Analysis results	① Axial rigidity mm (axial movement)	0.020	0.150
	② Moment rigidity deg (bearing inclination angle)	0.04	0.25



Example of analysis ① (Axial rigidity) Example of analysis ② (Moment rigidity)

Fig. 13 FEM analysis example

5.4 Weight

Table 2 shows the comparison of weight between the conventional bearings made of steel and the developed product of the equivalent size. The developed bearings reduced the weight by 63% for the separable type and 73% for the non-separable type compared to the conventional bearings, resulting in a significant weight reduction.

Table 2 Weight comparison between developed bearing and current bearing

Bearing type	Current bearings (separate crossed roller)	**Developed bearings** (separate crossed roller)	**Developed bearings** (non-separate, deep groove ball)
Appearance			
Bearing size mm	ϕ40×ϕ110×29		
Weight kg	1.00	0.37	0.27
Reduction factor %	—	63	73

6. Conclusion

We have discussed the lightweight bearings for robots developed by **NTN-SNR**. We have also summarized the recent trend and new technologies of the robot industry and the resulting requirements to the bearings in **Fig. 14**.

As shown in **Fig. 3**, the control of axis for the robot motion has been emphasized until now. However, it is believed that the requirements on being lightweight and lower in cost will be more emphasized more in the future instead of high speed and high rigidity, due to the increasing control with image processing and support of workers by cobotics.

We developed the bearings for robots discussed in this paper to cope with this trend. We will continue our development with a close eye on the trends of the robot industry and are poised to contribute to the development of the European and global industry by providing this product for various industrial robots.

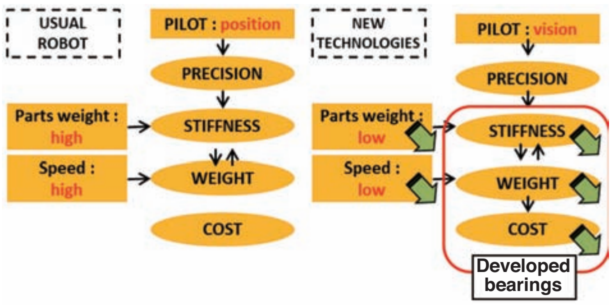


Fig. 14 Technology trend for robot and requirement of bearing

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