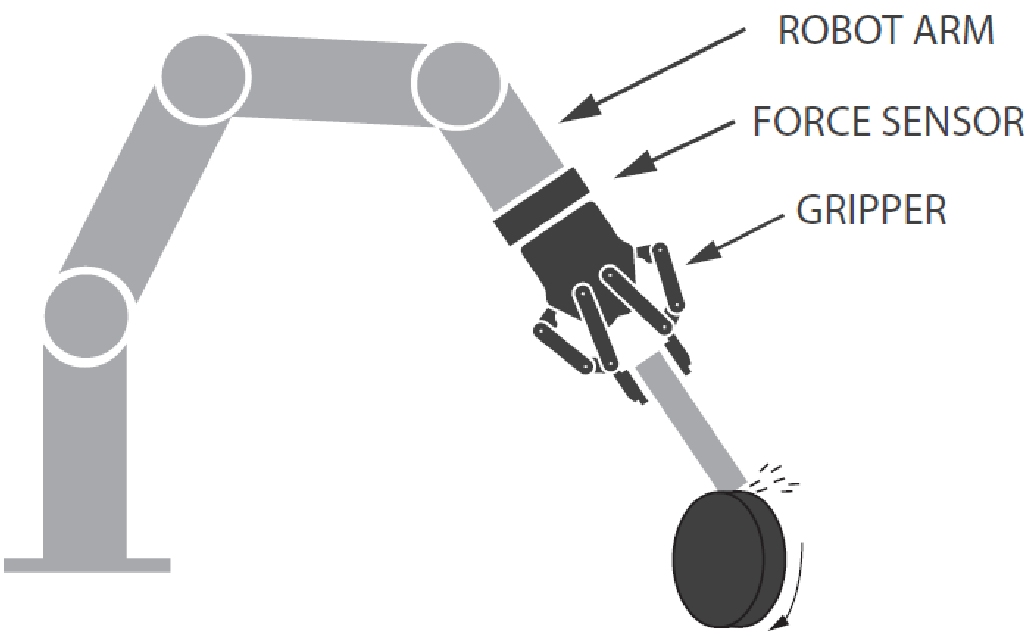
Force Torque Sensor - An Introduction

What is a Force Torque Sensor?
How does it work?



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INTRODUCTION

With the integration of robots in a wider variety of applications there is a need to give them a stronger ability to sense objects. As many robots now have the capability to 'see', it would be great if they could also add the capability to 'feel' what they are doing. This is the main objective behind force torque sensors.

These devices give a sense of 'touch' to the robot. Yet, force torque sensors are not the same as tactile sensors, which means that they don’t feel the actual object that is being grabbed, but rather they feel force exerted in all directions. This also means that a force torque (FT) sensor can apply a given force or torque for certain applications. Being able to control the amount of force or torque applied in certain applications opens up a whole new range of applications to robots. If we think about assembly or polishing, these are all applications that require a sense of feeling. The following eBook will help you figure out what are the main features of a FT sensor and more generally in what types of applications these features would be most useful.

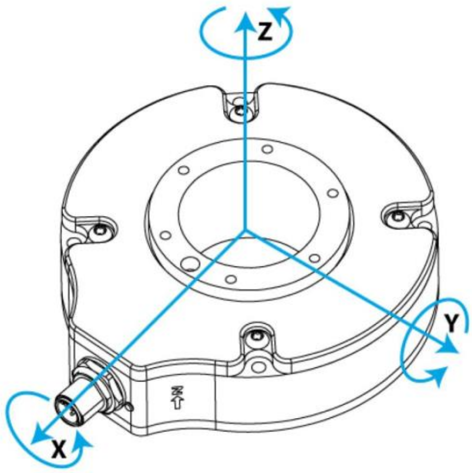
1. FT Sensor - Basics Principles

What Is a Force-Torque Sensor?

A FT Sensor is a device that is fitted onto the end of the wrist of a robot arm before the tool. Its purpose is to detect forces and torques applied at the robot tool. It can either sense forces created by the robot (i.e. robot pushing against an object) or external force (i.e. grinding wheel).

What Does 6-Axis Stand For?

6-axis stands for the 3 geometrical axis (X-Y-Z) and the rotations around them (3 axis + 3 rotation). So basically, the sensor can detect the forces in all three directions and the torques around those directions (axis). It can also combined measurements for all these forces and torques, and then the signal can interpret what is happening at the robot tool.



How Does the Sensor Feel the Force?

The casing part of the sensor is attached to the robot wrist. And the moving part is attached to the tool side. When a force is applied on the tool, the sensor reads the distance that the moving part has moved from the casing, depending on the amplitude of the displacement, the sensor returns a force signal to the computer. With the Robotiq FT 150 & 300 sensor, this reading is digital right from the start, making the signal very clean with minimal inherent noise and immune to external electromagnetic noise.

Robots are frequently used because of their rigidity. Most applications need rigidity to accomplish the precision necessary in the application. However, having a rigid robot that cannot adapt its motions if a disturbance or an unplanned situation occurs is a set up for problems. For example, if a shaft needs to be inserted into a hole by a robot, the parts can be damaged due to a misalignment of the robot or the part. The robot is not sensitive, it doesn't know if the shaft is entering in the hole the way it is supposed to. As robots are programmed to execute given motions at a given speed, there is no way to acquire feedback on the motion itself. Companies need to find a way to give a sense of feeling to the robot. The same kind of feeling that a worker would feel. If the shaft is misaligned, the worker will feel resistance, because he needs to apply more force on the shaft and will automatically adjust his/her movements.

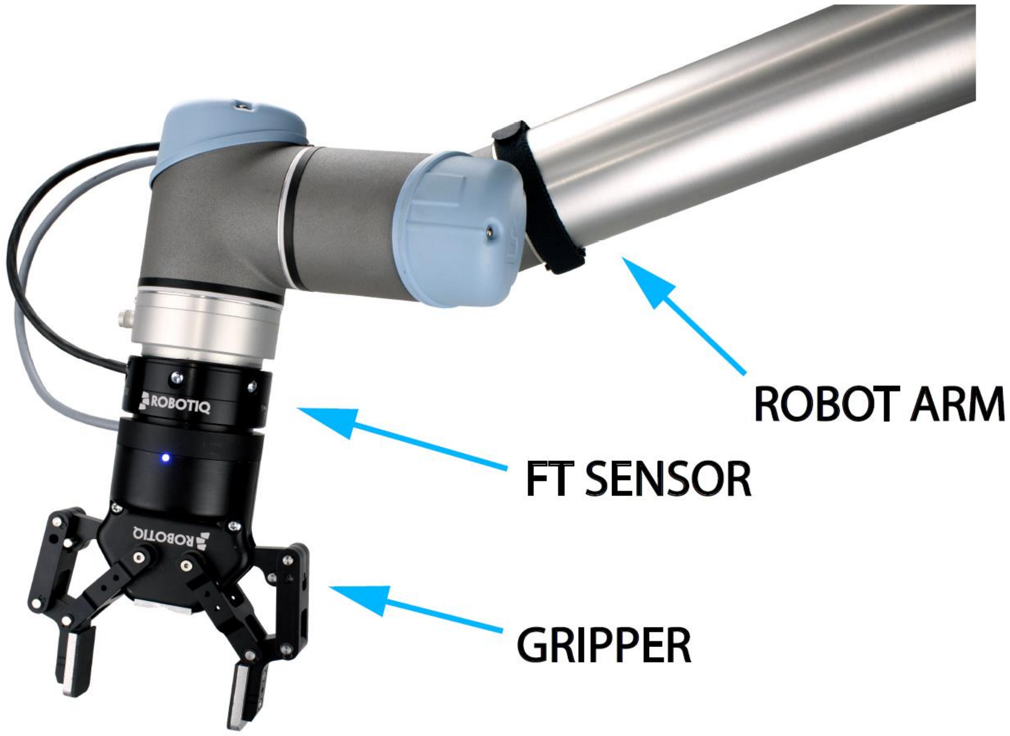
What Does "Force-Torque" Stand For?

A force torque sensor detects the different forces that are applied on the robot tool in the 3 geometric axes (X-Y-Z). The sensor also detects the torque applied around the 3 different axes. Which basically means that the sensor feels what is going on in all axes. By doing so, the sensor gives feedback to the robot and can adapt its motion to feel the minimum of force that is applied to it. Once the sensor is feeling an acceptable amount of force/torque (threshold), the robot can continue its motion without risk. Notice that some sensors can measure force only for a specific axis for a specific application.

2. FUNCTIONALITIES

Most robotic applications require a multi-axis or 6-axis FT sensor to give feedback to the robot about the tool itself which can be controlled via these 6 measurements. To measure the effort in all six axes, the sensor usually combines information from a minimum of 6 unitary measuring elements such as strain gauges. Using the geometry of these elements and the physical properties of the material on which they are installed, the sensor can then compute the force and torque along the axes which are meaningful to the robot control loop. When installed on the robot flange, the integrator needs to set the parameters for the relative position and orientation of the sensor with respect to the robot tool.

As you can see in the picture, the sensor is between the robot wrist and the tool. This position allows the sensor to feel the force and torque applied on the tool.



FORCE TORQUE SENSOR MEASURING METHODS

There are various ways to measure a force, generally most of the sensor manufacturers use strain gages with a specific orientation. Having a certain number of gauges would give enough information to the controller/computer to determine the intensity and the direction of the force/torque. Some FT sensors use gauges that digitize the measurement from the start, getting rid of the possibility of electromagnetic noise sensitivity interference, which is an issue experienced with traditional strain gauges.

FT SENSOR COMMUNICATION

FT sensors will output either an analog or digital signal. The signal is the communication method sent to the robot via an analog or digitized input and sent over a field-bus. Analog signals are not ideal in the typical industrial robotic environment which are known for their high level of electro-magnetic noise. For example our FT sensor that is used with the Kinetiq Teaching technology is using a digital signal and is therefore not affected by the electric motors or welding torches used in the welding process. This increases their accuracy and makes them more reliable.

FT SENSOR IN THE CONTROL LOOP

Most robot manufacturers provide software packages that use the information from the sensor(s). This allows the user to program the robot using high level commands. The user can also access the force torque data from the sensor and specifically program the desired control of the robot arm and end effector. In these instances the output of the sensor is used to close the loop in the controller, adjusting each of the joint's torque to match the desired output. Robot force control is useful in applications where the robot needs to interact with a rigid environment or fixture work piece. These are cases where the robot needs to be reactive to its environment.

3. APPLICATIONS

As the force torque sensor can read both force and torque, it would be good to understand, which types of applications requires force readings and which types require torque readings. Some applications will use the readings separately, but most applications will use both readings to have good precision.

WHICH APPLICATION REQUIRES FORCE READING?

An application that we are seeing often with the sensor is the bench test application. A robot is paired with a sensor and a gripper and is performing some cyclic action on a product. Where the sensor gets involved is when a given amount of force has to be applied. The robot can apply a limited force that has been set and it can also monitor this force. This means the product is tested at a given force and the force is monitored to see if there is any change in the behavior of the product. It can predict potential failure and determine the product life cycle.

WHICH APPLICATIONS REQUIRES TORQUE READING?

Hand-guiding would be an example that uses the torque information. Hand-guiding is the action of guiding a robot with your hands. This means you have to apply a certain amount of force on the tool to teach the robot a path, for example. As the force is applied on the tool (that is located after the sensor), you create a torque. This torque can be read in all directions and the signal can be sent in the control loop to make the robot move

WHICH APPLICATION REQUIRES BOTH?

Assembly tasks would be an example of applications that require both force and torque readings. In fact, in an assembly line, you can encounter different problems (misalignment, tight fits, etc.). You might combine your assembly with a bench test, so that you can test a given feature of your assembly, for example.

Now that you can tell what kind of applications require which kind of reading, let's see what applications are presently using the force torque sensor.

1. Grinding/Polishing

Grinding and polishing need to be done with a lot of precision and even with classic ‘manual’ methods it is hard to obtain a repeatable result. By using a force torque sensor, the robot can execute a smooth motion with a force threshold, so it doesn't grind too hard on a particular portion of the part. The final result is nice and neat, and all the parts look exactly the same. Medical parts such as replacement knee caps are being polished using a force limited 6-axis robot. Since the surface finish has to be

perfect and no imperfections can be allowed, a force torque sensor makes sense.

A robot can perform different polishing steps at a same station. For example, a machined part enters the robotic cell and is grasped by the robot. The robot can then preform a grinding operation using a rough stone or sandpaper. It can then switch to a thinner sandpaper or polishing compound to complete the application and produce the exact desired finish. The cell is then compact and a single robot can be used. Applications such as deburring can also be done using the same principle.

2. QUALITY CONTROL

Another branch of applications would be quality control or product testing, in fact some industries need to measure or test a certain motion on a product with a constant and regular force, a force torque sensor would work well for this kind of application. If the part doesn't fit well or where it should go, the robot has feedback and can readjust its motion to put the part in the right position.

3. ASSEMBLY

Imagine yourself assembling a given product without feeling what you are doing with your hands… You would never be able to know if the parts are being inserted in the right way. It is almost the same thing for a robot. It has a given path that it is supposed to follow. If the part is supposed to be inserted into another piece and those two parts are misaligned… nothing can tell the robot that something is wrong except a force torque sensor. In fact, once the FT sensor feels an abnormal force, it realigns itself to put the least force possible on the object.

Watch the following video for a better idea of an assembly task that uses a force torque sensor.

4. HAND GUIDING

Some industrial robotic applications need a collaborative feature. In fact, using an industrial robot in collaborative mode can have a lot of advantages. In collaborative mode you can save programming time or redesign a robot path in a few minutes. Technology such as Kinetiq Teaching use a force torque sensor to teach the robot how to weld. This technology saves significant time for the shop and a welding path can be designed in a few minutes without deep programming knowledge.

Many applications uses force torque sensors, we can think about haptic technology or teleoperation that both use force limiting operations to give a sense of touch to the human operator through a mechanical interface or vice versa. Force torque sensors are probably the next big advance in the robotic industry. So, make sure to investigate this technology and to think about how you could use it for your applications. It can save valuable programming time via the hand-guiding functions or improve quality control by increasing the accuracy of your applications. All in all it is a powerful addition that can be added to many applications.

4. SPECIFICATIONS

Remember when you were buying your first computer, there was a lot of technical data to compare, so you probably ended up asking the salesperson 'What was the close quote for me?' However, at the moment you cannot go to the closest robot store and ask for the best force torque sensor. The following section explains the basics on FT sensor specifications. So you can determine what is best for you.

4.1 SIGNAL SPECIFICATION

There are basically 2 different types of specifications that you need to understand. First the signal specifications which refers to the electronic side of things. There is also the mechanical specifications which refers to the physical attribute of the sensor.

FORCE AND TORQUE MEASURING RANGE

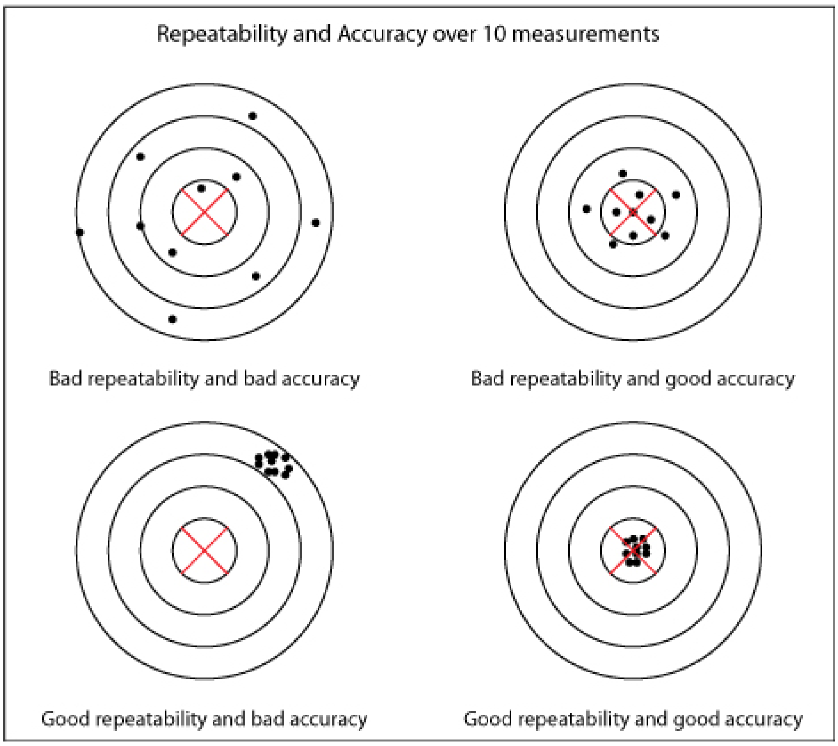
Most sensor manufacturers will rate their measuring range with a +/- sign. This means, for a +/-150 Newton sensor, it can measure 150 N in each direction. In other words, the sensor can measure the lift (pull) of a part, including the part's weight, up to 150 N and it can also measure the applied force (push) up to 150 N in any direction as well. Most of the time sensors can be overloaded. Take note that if an application needs a given force (ex: 100 N) you should use a sensor that can sense more than the required force (ex: 150 N).

PRECISION - RESOLUTION

Resolution is the minimal change in force that the sensor can measure. The resolution needs to be graded sufficiently to distinguish between events that are pertinent to the robot application. A sensor will need a higher resolution if the applications need more precision or if the parts are really light. For rough applications and heavy parts, the resolution can be coarser.

PRECISION - ACCURACY

Does the sensor measure precisely the applied force and torque? If the force is 50 N, does it really measure 50 N? It is really important to have good accuracy in the use of a force torque sensor, because some robot control software use dynamic models in which the actual force value is important.



PRECISION - REPEATABILITY

If you apply exactly the same force twice, will you obtain the same value each time? Depending on the application, you may want to have good repeatability, instead of good accuracy, to have a process that is the same again and again.

DRIFT

The signal is drifting when the sensor is reading a changing force even if no real force is being applied to the sensor. Force measurements are often used in a control loop. A drift in the measurements here will generate false values that will cause unwanted behavior. For example, a sensor drift in hand-guiding will cause the robot to move even if nobody is touching it. Drift can be affected by different environmental aspects like temperature and humidity. By calibrating and recalibrating the sensor often, you reduce your risk of drift.

NOISE LEVEL

Noise can be described as virus that is affecting the value of the read by the sensor. If the sensor's signal is analog, then this noise is added to the force signal. A high level of noise will require signal filtering, reducing the effective bandwidth of the sensor and adding delay to the reaction time of the robot.

Some sensors, particularly sensors with a digital signal are immune to external electrical noise. This means that the signal is not effected by external noise and that the signal is clearer, so there is no need to apply a filter on the signal. Also it will mean that the sensor is exchanging more accurate information with the robot, reducing delays.

OUTPUTE RATE

This is the number of force readings per second that the robot can read from the sensor. Most sensor manufacturers will express this specification in Hertz (Hz). For example 100 Hz, means 100 reading per second or a reading every 0.01 seconds. The output rate needs to be sufficient to feed the control loop in the robot program, so that it remains stable.

4.2 MECHANICAL SPECIFICATIONS

DIMENSIONS

Basically all the external dimensions are important to determine if the sensor will physically fit your robot. Thickness can also be an interesting specification to consider since it will influence the distance between the robot wrist and the robot tool.

ROBOT FIT

Sensors are often designed in order to fit well on specific robots. Although you can fit most sensors on different kinds of robots. Manufacturers provide adapter plates that can be attached between the robot wrist and the sensor.

Robotiq is providing a bundle to fit your FT 300 Force Torque sensor on a Universal Robots. In fact, this bundle makes your mechanical and software integration a lot easier.

WEIGHT

The robot you are using has a certain payload and if you add a sensor, a gripper and some adapter plates, each addition is reducing the functional payload of the robot. Make sure to sum all the components that will be attached onto your robot wrist to make sure it can still perform the application you have in mind

5. FT SENSOR BUNDLE FOR UNIVERSAL ROBOTS

This section presents the package for the FT 300 Force Torque Sensor on Universal Robots. This pairing will allow you to create a whole new array of applications for this popular collaborative robot.

WHY USE A FORCE TORQUE SENSOR?

Some of you may ask: **Why put a force torque sensor on a Universal Robot?**

In fact, the collaborative robot already has sensors to measure force and torque. Unfortunately for specific tasks, the robot measurements might not be precise enough. The robot reads the current in its motors and uses the length of its segments and a calculus matrix to determine the force applied on its tool. However, depending on the configuration of the robot, the force might be misinterpreted. By using the 6-axis FT 150 or 300 at the wrist, you can directly measure the forces being applied on the tool, making your readings and applications more accurate.

EASY INTALLATION

The FT/UR bundle includes all the accessories that are needed to install the sensor easily. First of all the appropriate hardware is provided with the bundle. Yet, the most important advantage of this package is that the sensor software and drivers can be easily and automatically installed onto the UR teach pendant by inserting a USB stick.

Through the FT programming the sensor is recognized and installed directly into the Universal Robots' interface. This allows the robot controller to directly read the force and torque measurements provided by the sensor. So there is no need to have another external controller that analyses the signal. The data can be read directly. Videos are available on our Robotiq YouTube channel to help you install the entire kit on your UR robot.

Important to remember, this kit will still allow you to install whatever tool you want at the end of the sensor.

6. ROS PACKAGE FOR FT SENSOR

Force torque sensors are used in research for many advanced robotic manipulations. At the same time, ROS is widely adopted by top academic and corporate research teams around the world. This is why it makes sense to develop a ROS package for the FT 150 Force Torque Sensor. This sensor and our other Robotiq devices can be programmed with ROS libraries.

How to Use the FT Sensor in ROS

The sensor is connected via the USB port of a computer. The signal has to be converted by a USB to serial port (RS-485).

The Sensor measures the forces and torques applied to the tool (which is in turn fixed to the sensor).

The ROS package provides all the required code to read what the sensor measures and transforms this into usable data. The forces are shown in terms of Newtons (N) and the torques are shown in Newton.meter (N.m). These units are shown as float variables.

The ROS package publishes the data at a rate of 100 Hz per topic. These topics are accessible by all the other ROS nodes.

The FT 150 Sensor package also provides a service that allows the user to 'zero' the sensor or provide a base referential reading. In fact, the program reads the actual value of force/torque as a reference and then shows the difference between the next value and the registered value.

ADVANTAGES

The ROS package makes it easy to use the FT 150 as a building block for your robotic application(s). In fact, in a couple of minutes, the sensor can be installed and ready to work with your robot. The user only has to follow the steps provided in the instruction manual.

ROS

''*ROS was designed to be as distributed and modular as possible, so that users can use as much or as little of ROS as they desire. We'll cover what components make up ROS elsewhere, but the modularity of ROS allows you to pick and choose which parts are useful for you and which parts you'd rather implement yourself.*'' **-ROS maintainers.**

The other advantage of ROS is that since it is designed to provide a standardize method to communicate with all your different types of robots, it means less individualized programming and ultimately easier communications.

As FT sensors move out of the research labs and into industry, ROS industrial will move along with them. As with the benefits of programming your robot using the UR Kit, using ROS industrial also takes the block or stack approach which makes programming much less complicated. And saving programming time is saving money, thus improving your bottom line, which is another great advantage of adding a force torque sensor to your application.

RELATED ARTICLES

- Why use ROS

- Robotiq's Adaptive Robot Gripper Now On ROS Industrial

CONCLUSION

Since this document was an introduction to force-torque sensor, it simply effloresces the subject of such sensors. There is various applications that can be done with such devices. It is only the beginning of their use, in fact a lot of the next generation of robots will have embedded FT sensor at their wrist. Since the level of autonomy and dexterity is enhanced, it is just a step forward in the future of robotics.

LET'S KEEP IN TOUCH

For any questions concerning robotic and automated handling or if you want to learn more about the advantages of using flexible electric handling tools, contact us.

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WHO WE ARE

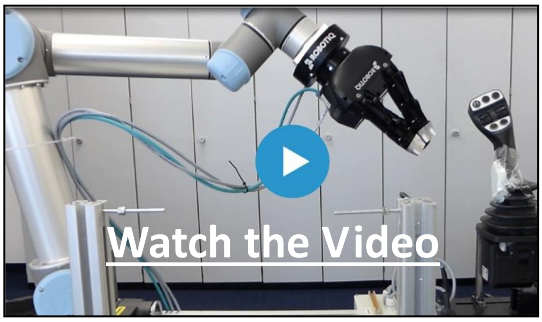
Robotiq exists to free human hands from tedious jobs. The fast-growing company designs and manufactures advanced robot grippers and a force torque sensor. Robotiq is based in Quebec City, Canada. It works with a global network of highly capable local partners to solve flexible automation challenges in more than 30 countries.

Popular Applications

Machine Tending

Use a **single, programmable,** **flexible robot gripper** to handle a wide variety of parts in your machine tending applications. **Reduce your tooling cost** and **eliminate changeovers** by using a single Gripper.

Product Testing



Implement a **flexible** production line testing application that uses an easy to integrate Adaptive Gripper designed to control grip force and be able to adapt to various geometries.

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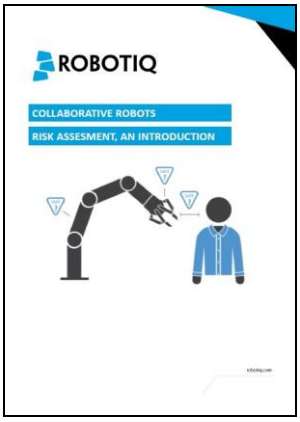
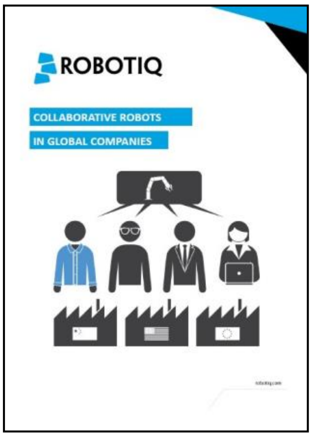


Collaborative robots risk assessment, an introduction



Collaborative robots in global companies