Industrial Robotics - Joint Structure

Grade Range: Secondary/ Post Secondary **Lesson Time: 50 minutes**

Key Terms	
Harmonic reducer	Pinion/rack
Hydraulic	Pneumatic
Involute	Rotational motion
Linear motion	RV reducer
Link drive	Synchronous drive
Motor screw	Worm gear

Materials and Resources
zView

Activity Overview

As robotic machines become more sophisticated and gain popularity in industrial, medical, and commercial markets, they are called upon to complete more complex tasks. Emerging design trends rely on smaller, compact assemblies with precision and high reliability. The motion control that defines robot joint movements must be as precise as possible to improve overall accuracy and fully utilize the robots' capabilities. Have you ever watched an industrial robot perform tasks endlessly, without error, moving smoothly and effortlessly? How does the robot move so quickly and quietly at varying speeds for hours upon hours each day?

Essential Questions

1. What are the types of movable joints in the industrial robot?
2. What are the types of rotary joints in the industrial robot?
3. When are these types of joints advantageous for the industrial robot?
4. How do these joints and drives differ from each other?

Objectives

- Successfully navigate the Industrial Robotics Expert application
- Manipulate the models in both Principle and Post-Explosion modes
- Analyze the differences in structure and capabilities among movable and rotary joints

Introduction

Prior to this activity, students should review the Composition of the Industrial Robot section and the Main Parameters of the Industrial Robot within the Industrial Robotics Expert application.

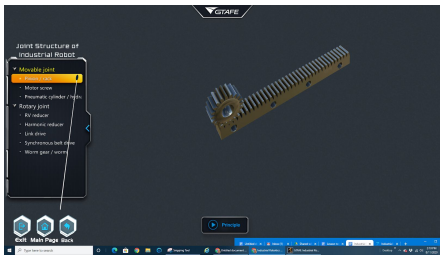
zSpace Activity

1. Open up the Industrial Robotics Expert application.

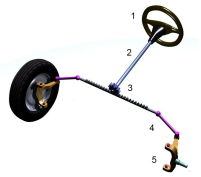
2. Select the Mechanical Structure.

3. Select the Joint Structure.

4. Select Pinion/Rack below Movable joint.
   A pinion and rack are together a type of linear actuator composed of a circular gear (pinion) engaging a linear gear (the rack), which operates to translate rotational motion into linear motion. Driving the pinion into rotation causes the rack to be driven linearly.

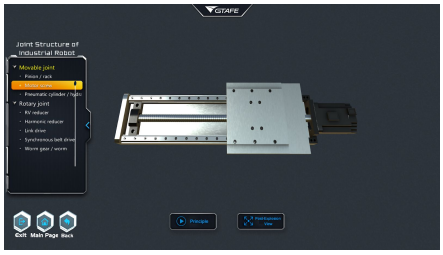


5. Using the stylus, select the Principle icon at the bottom and observe the pinion and rack motion.
   Can you think of other applications where you might have seen rack and pinion motion?

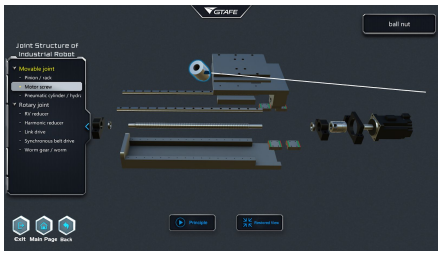


   For example, have you observed it being used for automotive steering?
   If you can access the Automotive Expert application from zSpace, research the steering system.
   The railway system uses the rack and pinion method extensively.

6. Select Motor screw from the left pane.
   The motor screw is also known as a power transmission screw, ball screw, or lead screw. Motor screws are typically used for converting rotary motion to linear motion.



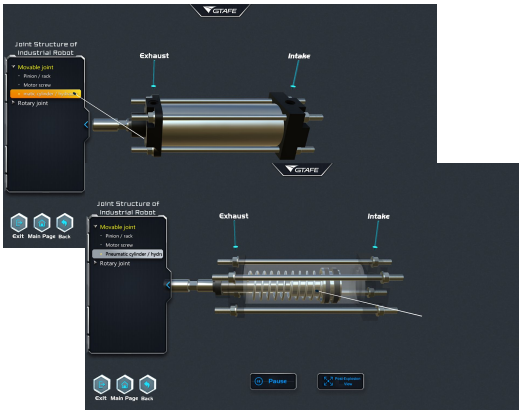
7. Select the Principle and Post-Explosion views. Using your stylus, explore the many parts of the motor screw assembly.



8. Note that each part can be grasped and explored separately while its name is displayed at the top right of the screen. Have you seen this motion around your school's lab areas? Have you, for example, seen screw motors used in your 3D printers or laser machines?

9. Select Pneumatic cylinder/hydraulic from the left pane.
   When a linear motion must be produced, hydraulic (fluid) and pneumatic (air) cylinders become the most important component by converting fluid pressure and flow to force and velocity. These cylinders are available in an endless array of configurations, sizes, and special designs. They are extremely versatile and allow for innovative designs.

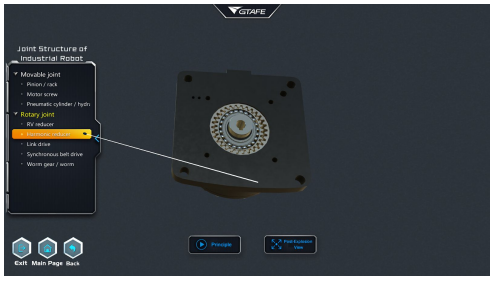
   Select the Principle and Post-Explosion buttons at the bottom.
   Note: Single-acting and double-acting cylinders can be viewed.



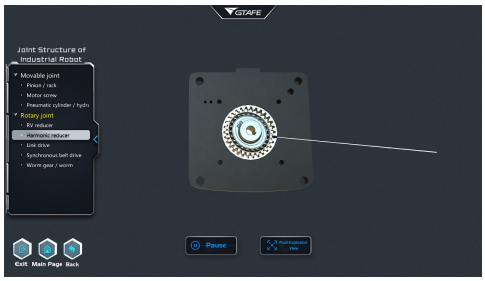
10. Select Rotary joint and RV reducer from the left pane.
    The RV reducer is a two-stage closed planetary gear train, which consists of involute gears and cycloid gears.
    The involute gear profile is the most commonly used system for gearing today. The profiles of the teeth are involutes of a circle. Search for images of involute gears. They may even appear in the logos displayed on the equipment in your school's labs. Search for and watch an involute gear animation.

    The RV reducer utilizes a cycloidal design, or cyclic symmetry structure that provides high torque, a high ratio, and significant shock load capabilities.

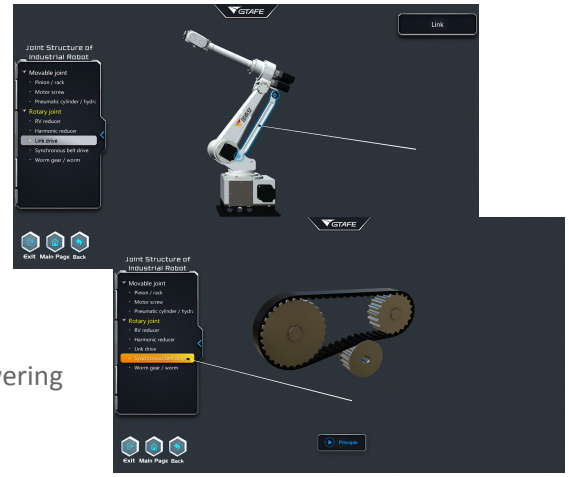
11. Select Harmonic reducer from the left pane.
    A harmonic reducer is a mechanical speed-changing device. It consists of a thin ring that deflects elastically as it rolls on the inside of a slightly rigid circular ring. The three main parts are the circular spline (rigid), the flexspline (output), and the wave generator (input). The ratio of the input speed to the output speed depends on the difference in the number of teeth in the circular spline and flexspline. Speed ratios as high as 320 to 1 can be produced in single-reduction harmonic drives.



12. Select the Principle and Post-Explosion buttons at the bottom.
    Closely review the Principle view to see the flexspline moving within the rigid outer ring.
    What do you think is the function of the flexspline within the harmonic reducer?



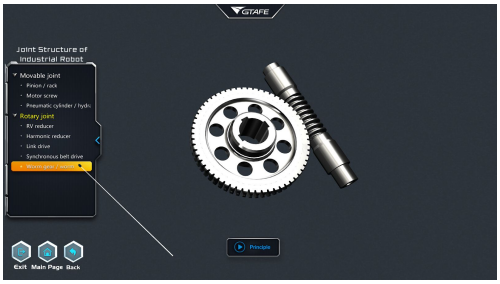
13. Select Link drive from the left pane. Note that the link is the highlighted blue, rigid member connecting the joints of the robot.



14. Select Synchronous belt drive from the left pane.
    This model demonstrates a type of drive belt in which the teeth of a synchronous belt mesh with the grooves in a pulley to transmit the power.

    Synchronous drive components improve the performance of motor-driven systems, increasing their energy efficiency and lowering maintenance costs. A synchronous drive allows adjustments to speed and torque while connecting mechanically connected components. The belts and pulleys utilize teeth to prevent slipping and unwanted speed variations.

    The belts may be constructed of neoprene with fiberglass reinforcement or polyurethane with polyester reinforcement and are available in various profiles and widths.



15. Select Worm gear / worm from the left pane.

16. Select the Principle button at the bottom and observe the worm gear in action.
    Worm gears are right-angle drives providing large speed ratios on comparatively short center distances from ¼" to 11". Worm gears are known to function as the quietest and smoothest-running type of gear. They provide high ratios with maximum speed reductions and operate on non-intersecting shafts at 90-degree angles.

17. How is a worm gear different from a rack and pinion?

18. What advantages does a worm gear offer over a rack and pinion?

Closing

Lead students on a brief but extensive tour of the nearby labs in the school and have them search for these types of joints and drives. The automotive lab will certainly contain rack and pinion assemblies and lots of hydraulic cylinders. The 3D printing or manufacturing lab will contain motor screws and synchronous belt drives. If robots are present, there will probably be harmonic reducers or RV reducers as well as link drives to examine.

Alternatively, have students perform a remote activity by searching for these devices around their homes or on the Internet, where they can view videos demonstrating the use of each component.

Differentiation

- Group students heterogeneously to allow students with a strong command of the English language to assist in reading or interpreting questions
- Provide paper copies of diagrams for students to use as a reference
- Provide a handout with a list of vocabulary terms and definitions that will appear in the activity
- Allow students to provide answers that are handwritten, typed, or verbal
- Give students a variety of presentation styles to choose from (using charts/graphs, slideshow presentations, making 3D presentations, creating videos/movies, making posters)