

## Introduction

**Goal: To improve the interface repeatability of an industrial robot by implementing kinematic couplings.**

- Kinematic couplings are precision machined components that deterministically constrain all six degrees of freedom of an interface.
- Kinematic couplings are frequently used as components of repeatable interfaces in ideal environments, but their use has been limited in industrial environments.
- A series of tests was conducted to assess the industrial repeatability performance of large kinematic couplings on two interfaces of an ABB 6400R industrial robot.

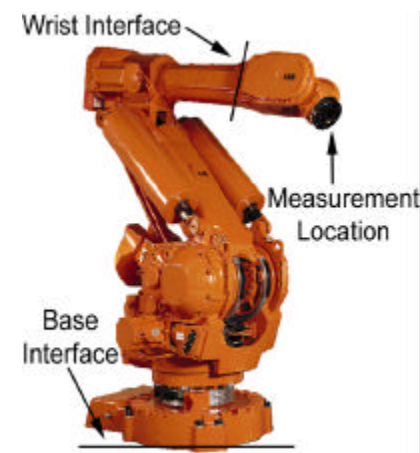


ABB 6400R Industrial Robot

### Wrist Interface

- Complex pin joint interface
- Maximum Forces of 30 kN and Moments of 30 kN-m
- 200mm by 200mm perimeter
- Secured by 8 M12 Bolts
- Average location shift of 0.12mm with standard deviation of 0.05mm

### Base Interface

- Pin joint interface with two pins
- Maximum Forces of 30 kN and Moments of 45 kN-m
- 1m by 1m foot print
- Secured by 8 M20 Bolts
- Average location shift of 1.6mm with standard deviation of 0.5mm

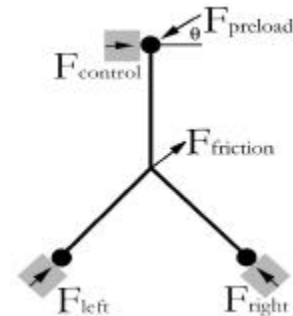
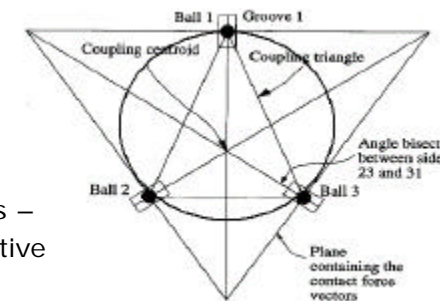
• Additional laboratory measurements were taken for comparison using the wrist interface plates in a controlled environment.

## Experimental Procedure

Two coupling forms were tested:

### Canoe Ball Coupling

- Load capacity and stiffness sufficient for mounting machines.
- Surfaces made by precision contour grinding.
- Design procedure based on Hertzian contact analysis – same as for simple ball/groove couplings, using effective sphere radius for groove dimensions and real sphere radius for stresses.



### Three Pin Coupling

- Form of quasi-kinematic coupling which deterministically constrains in-plane degrees of freedom and uses large surface contact to constrain the remainder.
- Load capacity and stiffness are comparable to existing designs.
- Design procedure based on force balance and Hertzian contact analysis.

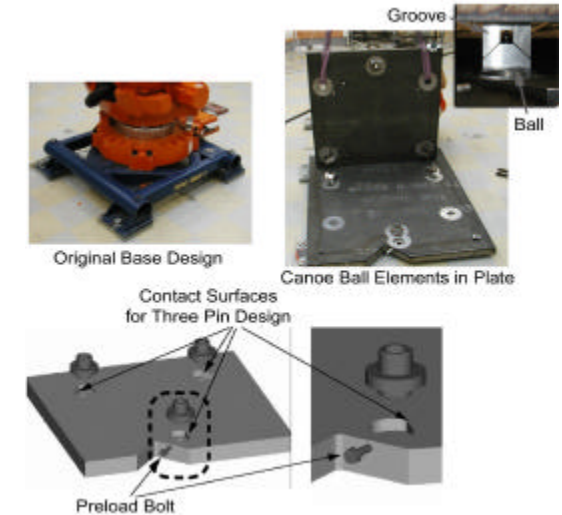
### Measurement Tools:

- Industrial** – Leica LTD500 laser-tracking measurement system with accuracy of 0.01 mm per meter between the retroreflector and the motorized laser-tracking device.
- Laboratory** – Lion Precision Capacitance Probes with resolution of 3.5 nm RMS.

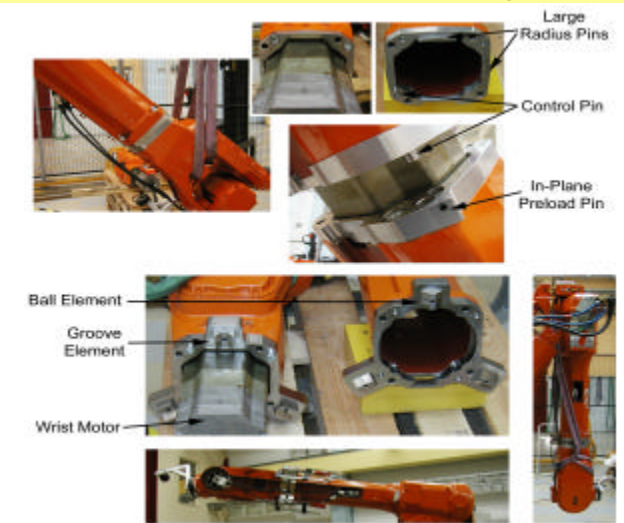
### Installation Procedure:

1. Remove preload bolts and separate coupling interfaces using support crane.
2. Inspect and carefully clean the contacting surfaces with methanol. Clean and grease all bolts. Surfaces were not lubricated during the experiments.
3. Engage coupling interfaces with special attention to alignment of elements.
4. Replace preload bolts and any additional bolts. Tighten bolts to design specification in a stepped fashion following a consistent pattern.

## Base Geometry

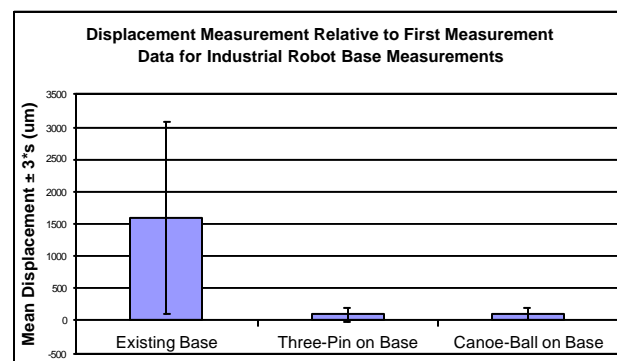


## Wrist Geometry



## Results

Both laboratory and industrial experiments demonstrated that installation procedure is almost as important as the form of coupling itself.



Experiment	Average Location Shift	Standard Deviation
Laboratory Canoe Balls - Unloaded	-0.04 µm	0.14 µm
Laboratory Canoe Balls – Design Preload	-0.69 µm	0.41 µm
Laboratory Three-pin – Design Preload	-0.09 µm	1.01 µm
Industrial Robot Wrist – Canoe Balls	50 µm	25 µm
Industrial Robot Wrist – Three-pin	80 µm	30 µm
Industrial Robot Base – Canoe Balls	110 µm	35 µm
Industrial Robot Base – Three-pin	100 µm	35 µm

