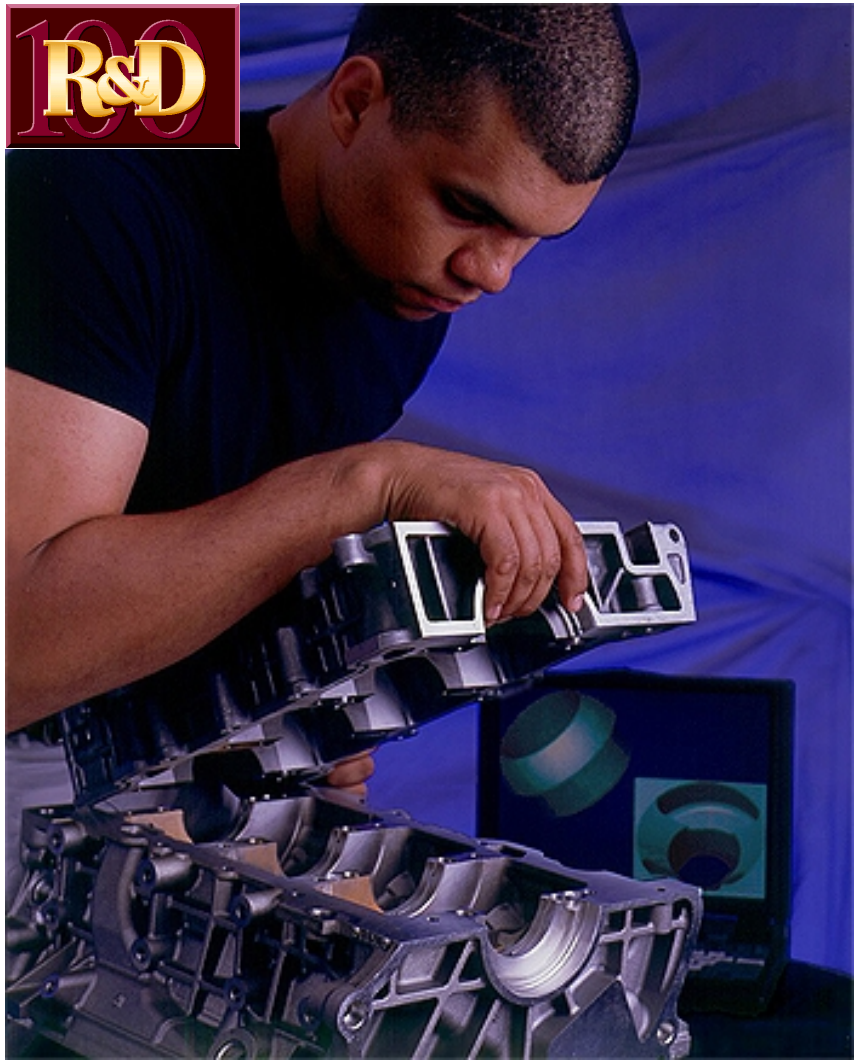
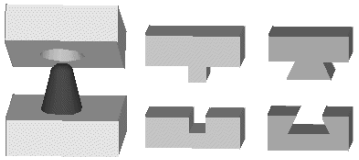
Quasi-Kinematic Couplings: US Patent 6193430



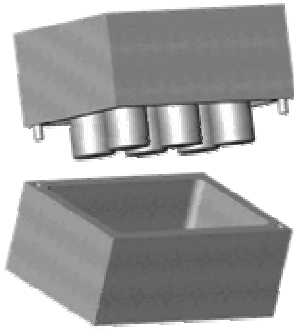
- **Motivation, Impact, & Contributions**
- **Intro. To Quasi-Kinematic Couplings**
- **Case Study: 6 Cylinder Engine**
  - **Application**
  - **Design & Manufacture**
  - **Performance**
  - **Design Comparison**
- **Other Applications**

Review of Common Coupling Methods



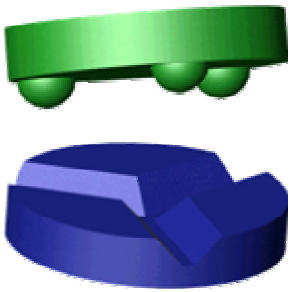
Elastic Averaging

Non-Deterministic



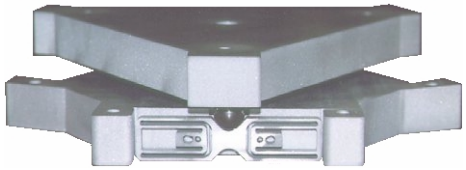
Pinned Joints

No Unique Position



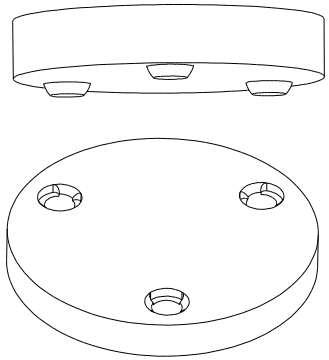
Kinematic Couplings

Kinematic Constraint



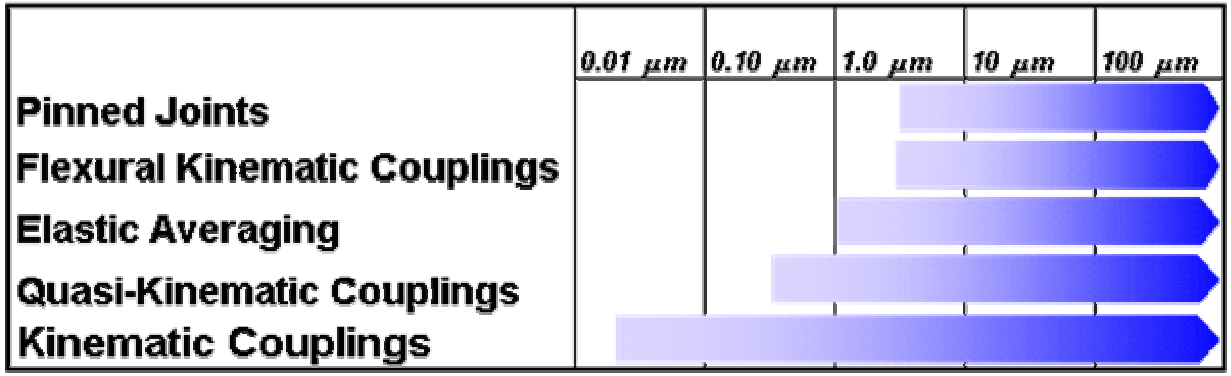
Flexural Kin. Couplings

Kinematic Constraint



Quasi-Kinematic Couplings

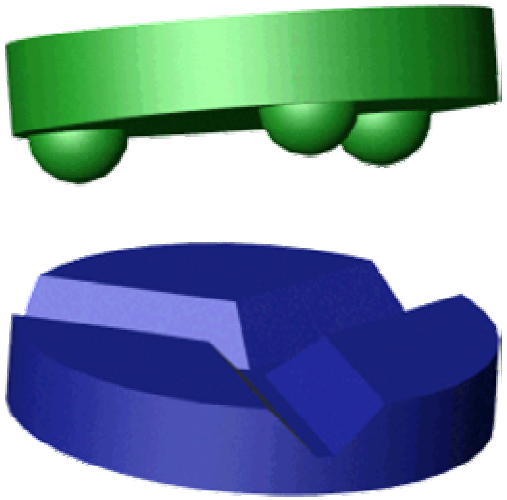
Near Kinematic Constraint



Kinematic Coupling Overview

Kinematic Couplings:

- # Points of contact = # Degrees of freedom constrained
- Low-Medium Force Precision Applications
- Do Not Allow Sealing Contact
- Moderate Stiffness
- Moderate Cost
- Excellent Repeatability



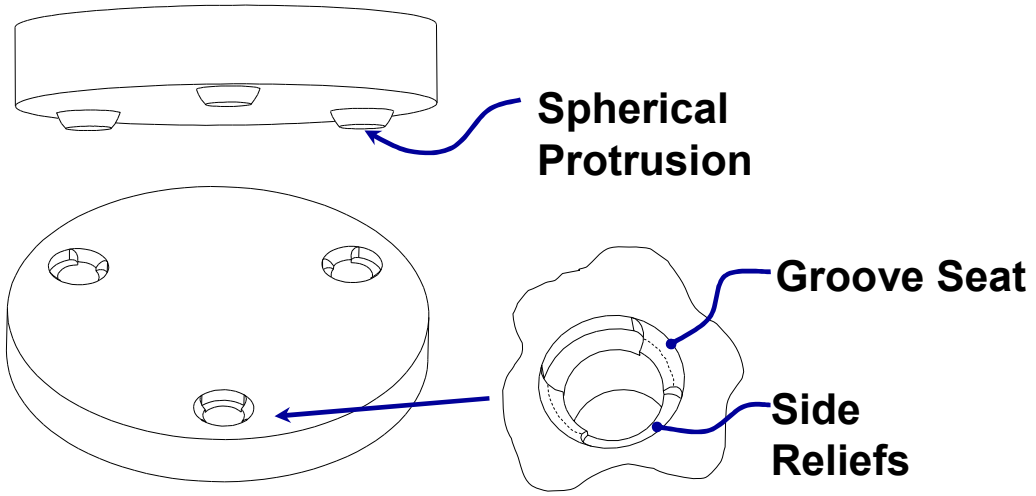
Recent Use in Manufacturing:

- KCs Low Volume
- FKCs Low -> Medium Volume

Physical Components of QKCs & QKC Function

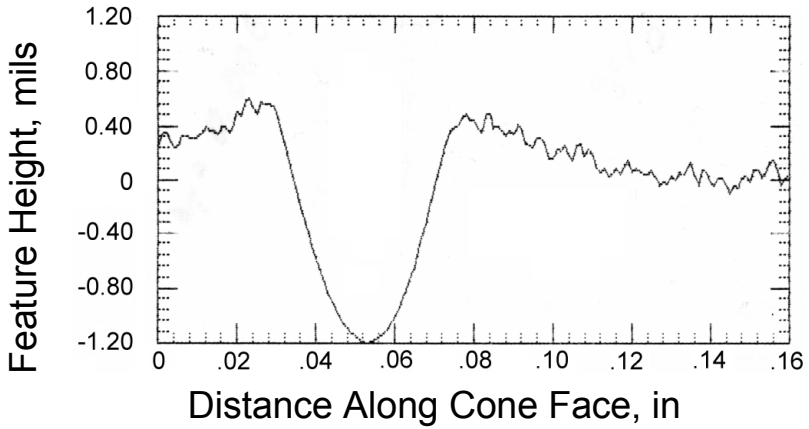
QKC Characteristics:

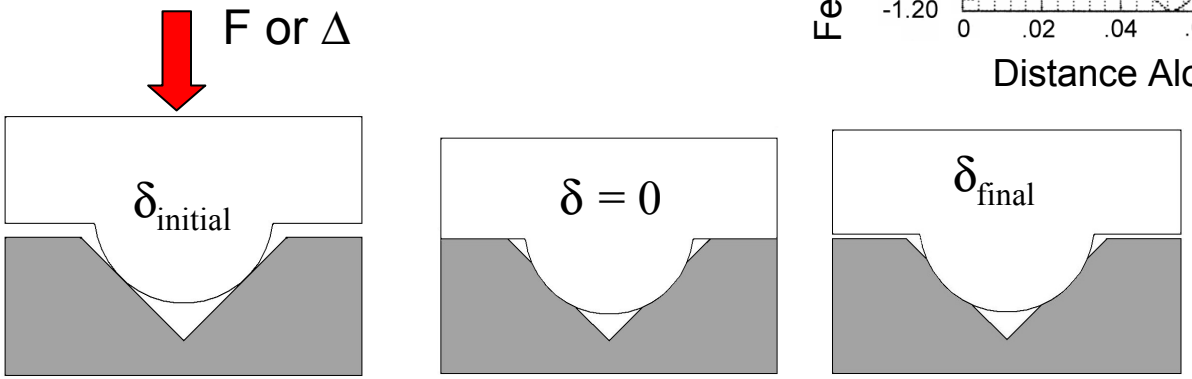
- Arc Contact
- Sub-micron Repeatability
- Stiff, Sealing Contact



QKC Function:

- Ball & groove comply
- Burnish surface irregularities
- Elastic recovery restores gap





What is a QKC & Why Is It Important

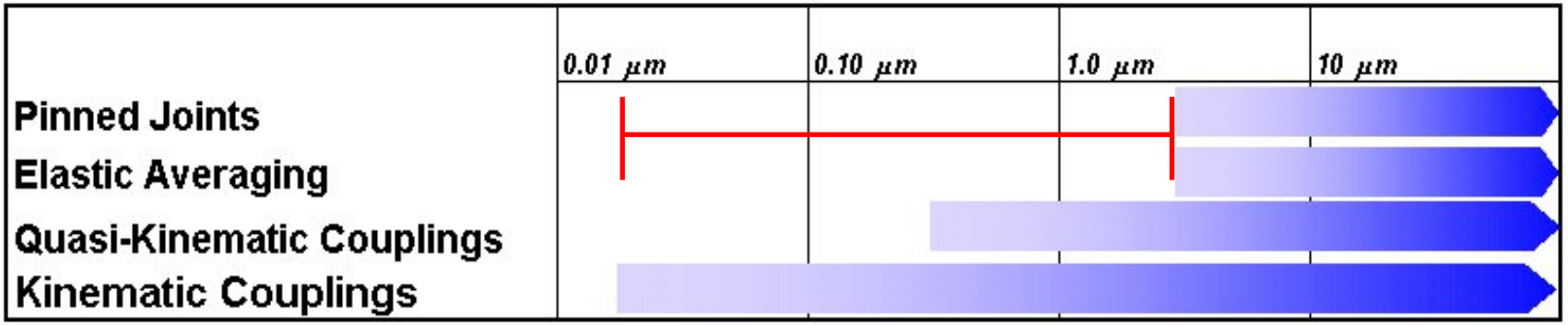
A QKC Is A Fundamentally New Coupling Which Enables Manufacturers To:

- Attain Sub-Micron Repeatability
- Use Less Restrictive Tolerances
- Have More Flexibility in Assigning Precision Tolerances

Impact of the QKC:

- Better Precision At Lower Cost
- Extension of Practical HVM Precision
- The QKC Will Eliminate Precision Pinned Joints (0.5 - 10 microns)

Typical Performance of Low-Cost Couplings:



The Need For Low Cost Precision: 6 Cylinder Engine

Ford Desires A Coupling Which:

- Is Inexpensive
- Can Form A Sealed Joint

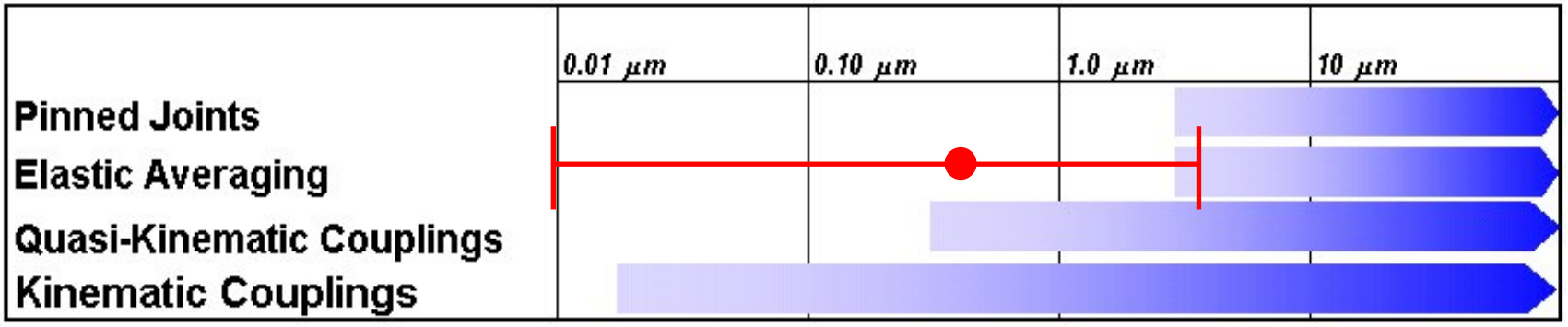
Repeatability: At Present They Have 10 microns

- Block Movement: ~ 5 microns
- This Leaves Coupling: < 5 microns
- They Desire 0 !

Characteristics:

- Ford 2.5 & 3.0 L V6
- > 300 000 Units / Year
- Cycle Time: < 30 s





Case Study: Ford 6 Cylinder Engine

Characteristics:

- **Ford 2.5 & 3.0 L V6**
- **300 000 Units / Year**
- **Cycle Time: < 30 s**

Constraints:

Sealing Contact - Required

Cost - Less Expensive

Tooling/Machinery - No Change in the Core Machinery

Joint Location and Size - Same Footprint & Location As Pinned Joint

Loose Pieces - Not Allowed

Material / Treatment - No Change Allowed

Case Study: Ford 2.3 L V-6 (Duratec^{TM})

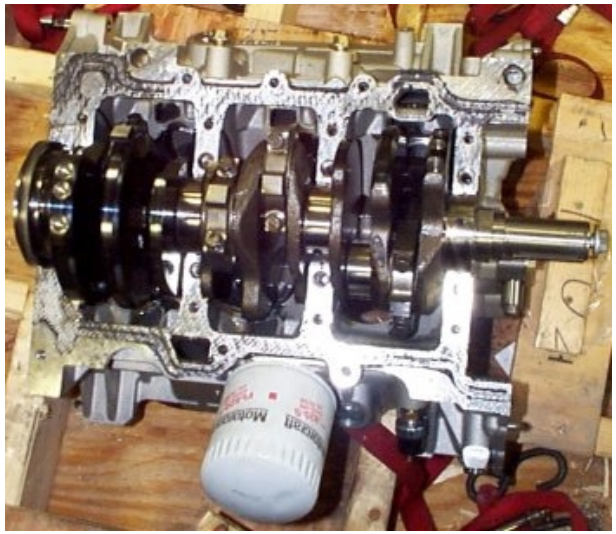
COMPONENTS



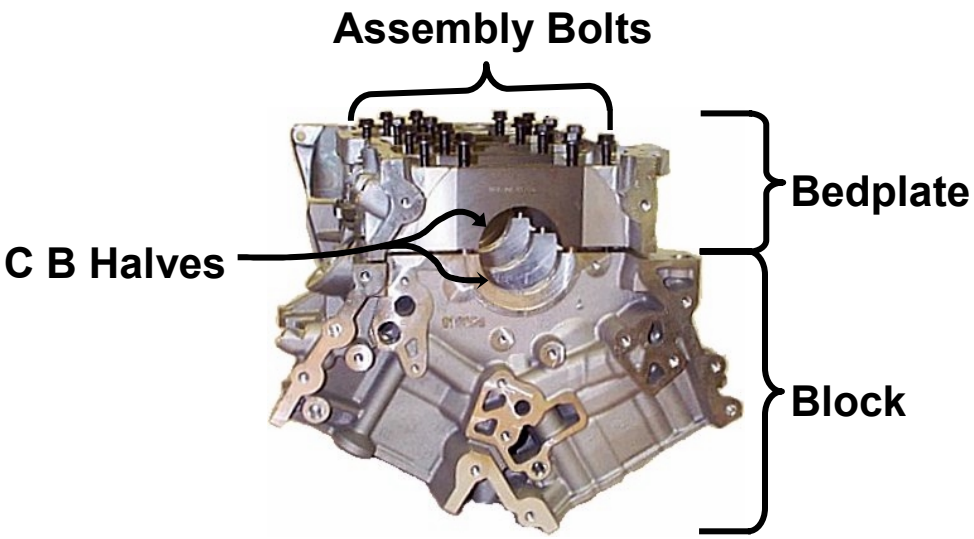
Block



Bedplate

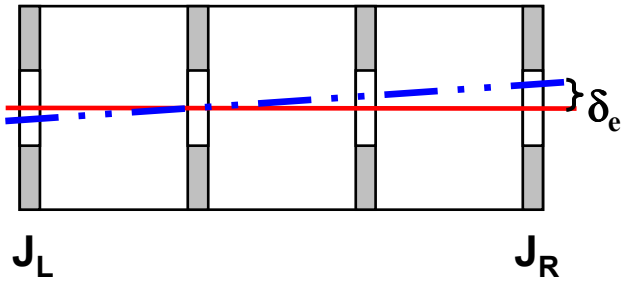


ASSEMBLY



ERROR

δ_e MAX = 5 microns

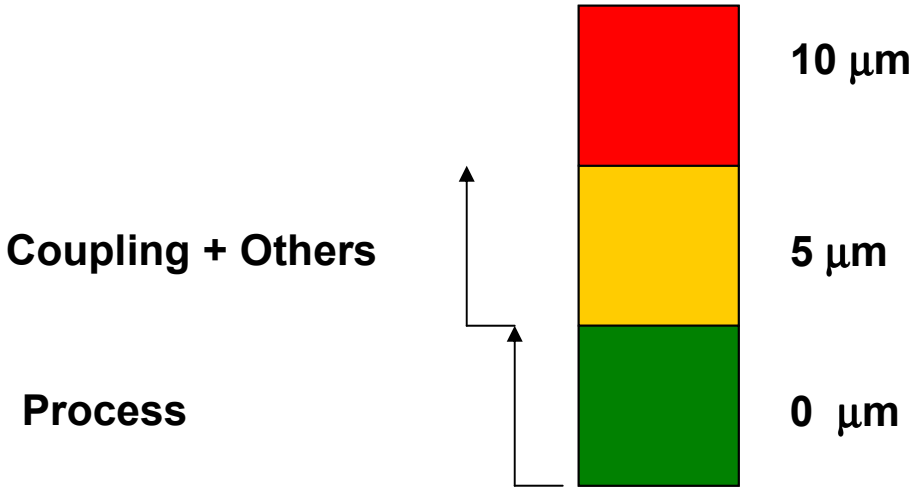




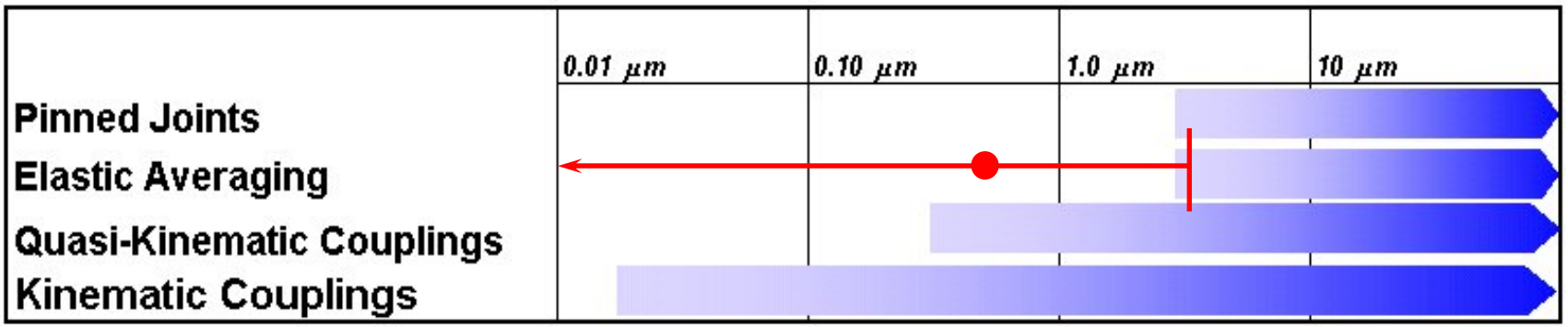
Case Study: Ford 6 Cylinder Engine

Repeatability: They Have 10 microns

- They Desire 0 !
- Process: ~ 5 microns
- Coupling: < 5 microns

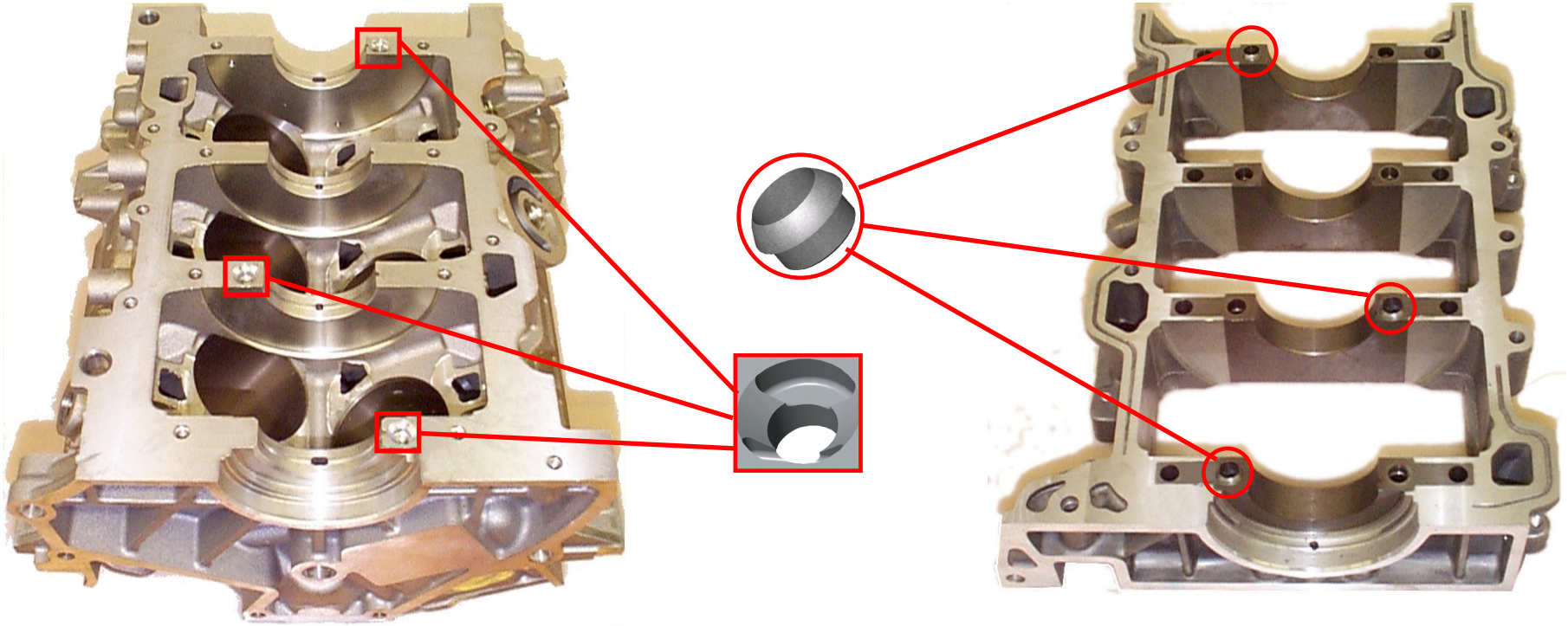


Rough Error Budget



IC Engine QKC Concept

CONCEPT



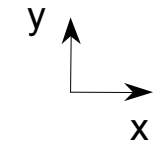


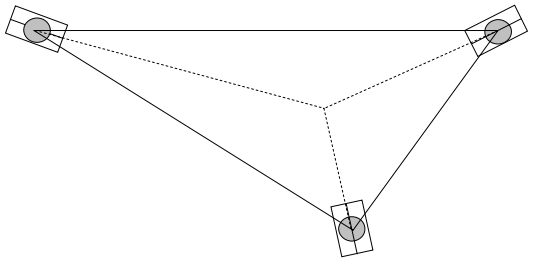


QKC Concept Detail

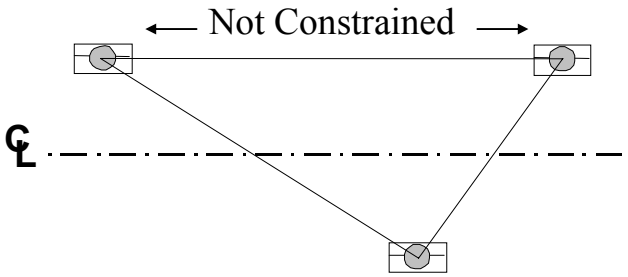
GROOVE LOCATION AND ORIENTATION

Kinematic Coupling Groove Mating Spherical Element QKC Groove

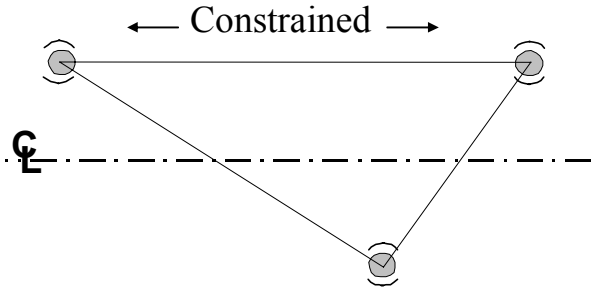




Kinematic Coupling



Aligned Kinematic Coupling



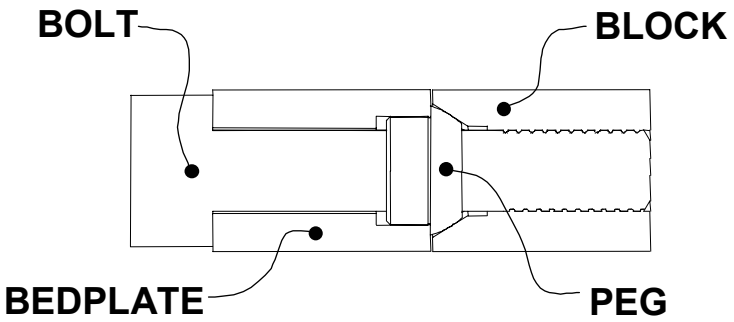
Aligned QKC

GROOVE MANUFACTURING

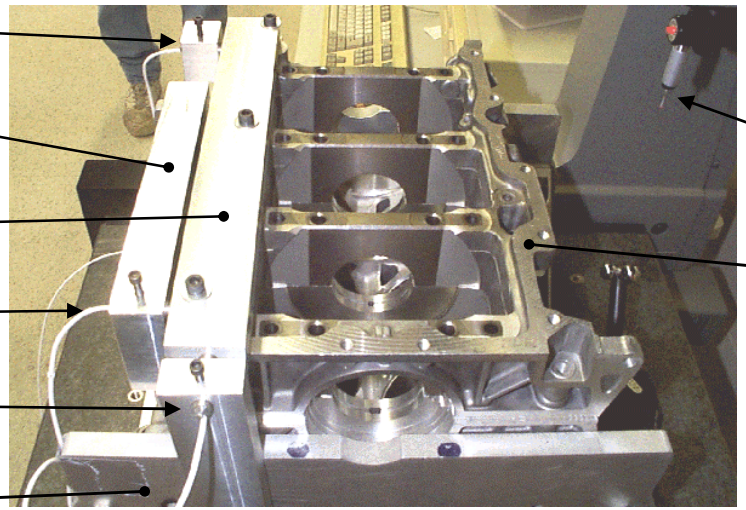


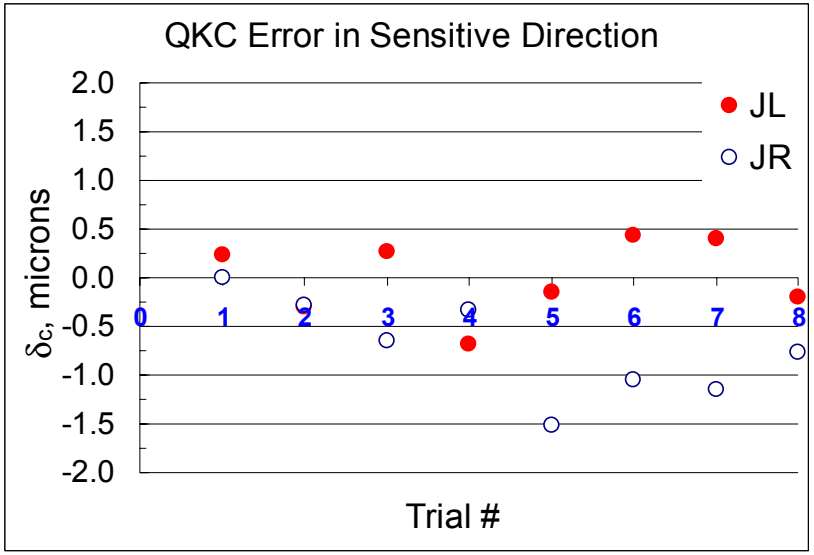
CAST FORM TOOL FINISHED

ASSEMBLED JOINT

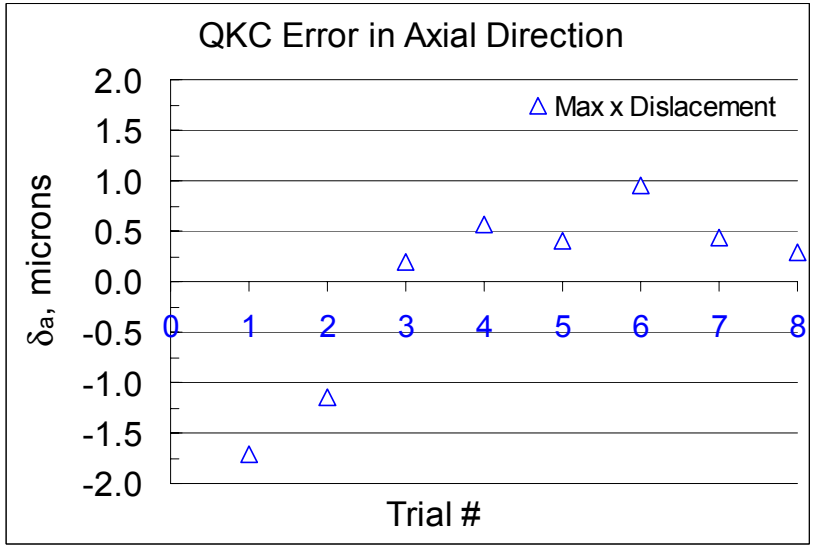


Engine Assembly Performance





$(\text{Range}/_2)|_{AVG} = 0.65\ \mu m$

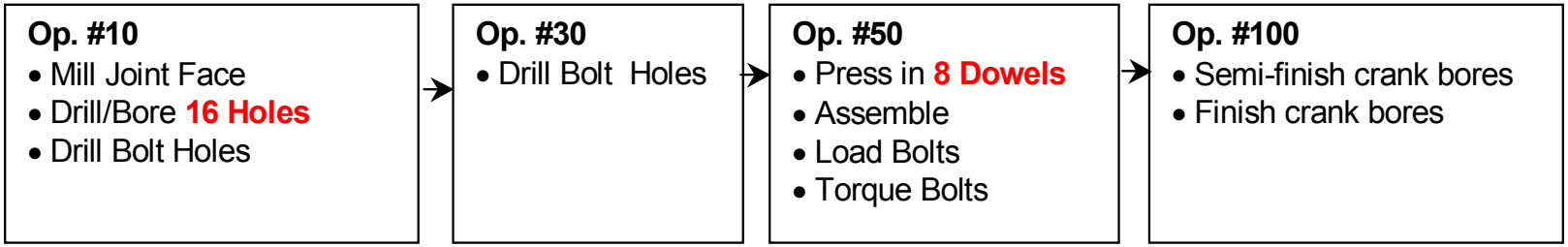


$(\text{Range}/_2) = 1.35\ \mu m$

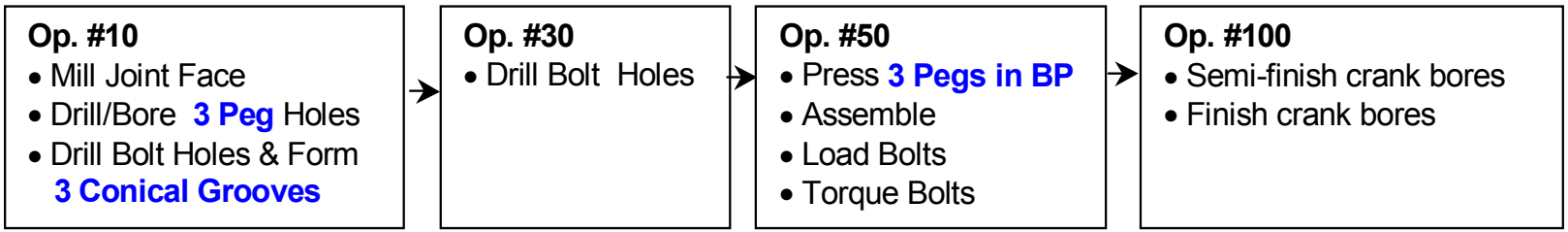
Engine Assembly Comparison

MANUFACTURING:

Engine Manufacturing Process With Pinned Joint



Modified Engine Manufacturing Process Using Kinni-Mate Coupling



DESIGN:

ITEM	QKC	Pinned Joints
# Precision Pieces	3	8
# Precision Features	3	16
Feature Placement Tolerance	+/- 0.08mm	+/- 0.04mm
Average Centerline Repeatability	0.65 μm	4.85 μm
Normalized $/Engine	0.64	1

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617.452.2395

