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

\[ \delta_{\text{initial}} \quad \delta = 0 \quad \delta_{\text{final}} \]
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:

<table>
<thead>
<tr>
<th>Pinned Joints</th>
<th>Elastic Averaging</th>
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<tbody>
<tr>
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<td>0.01 μm</td>
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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

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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™)

COMPONENTS

- Block
- Bedplate

ASSEMBLY

- Assembly Bolts
- C B Halves
- Bedplate
- Block

ERROR

\[ \delta_e \text{ MAX } = 5 \text{ microns} \]

\[ \begin{align*}
J_L & \quad \delta_e \\
J_R & \quad \text{Block Bore} \\
& \quad \text{Bedplate Bore}
\end{align*} \]
Case Study: Ford 6 Cylinder Engine

Repeatability: They Have 10 microns

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

Rough Error Budget

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IC Engine QKC Concept

CONCEPT
QKC Concept Detail

GROOVE LOCATION AND ORIENTATION

- Kinematic Coupling Groove
- Mating Spherical Element
- QKC Groove

- Not Constrained
- Constrained

Kinematic Coupling
Aligned Kinematic Coupling
Aligned QKC

GROOVE MANUFACTURING

CAST + FORM TOOL = FINISHED

ASSEMBLED JOINT

BOLT
BLOCK
BEDPLATE
PEG

MIT Precision Systems Design & Manufacturing
MIT Precision Engineering Research Group
Ford Scientific Research Laboratory
http://psdam.mit.edu
http://pergatory.mit.edu
Engine Assembly Performance

- \( (\text{Range}/2)_{\text{AVG}} = 0.65 \, \mu\text{m} \)
- \( (\text{Range}/2) = 1.35 \, \mu\text{m} \)
Engine Assembly Comparison

MANUFACTURING:

Engine Manufacturing Process With Pinned Joint

Op. #10
- Mill Joint Face
- Drill/Bore 16 Holes
- Drill Bolt Holes

Op. #30
- Drill Bolt Holes

Op. #50
- Press in 8 Dowels
- Assemble
- Load Bolts
- Torque Bolts

Op. #100
- Semi-finish crank bores
- Finish crank bores

Modified Engine Manufacturing Process Using Kinni-Mate Coupling

Op. #10
- Mill Joint Face
- Drill/Bore 3 Peg Holes
- Drill Bolt Holes & Form 3 Conical Grooves

Op. #30
- Drill Bolt Holes

Op. #50
- Press 3 Pegs in BP
- Assemble
- Load Bolts
- Torque Bolts

Op. #100
- Semi-finish crank bores
- Finish crank bores

DESIGN:

<table>
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<tr>
<th>ITEM</th>
<th>QKC</th>
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<tbody>
<tr>
<td># Precision Pieces</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td># Precision Features</td>
<td>3</td>
<td>16</td>
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<tr>
<td>Feature Placement Tolerance</td>
<td>+/- 0.08mm</td>
<td>+/- 0.04mm</td>
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<tr>
<td>Average Centerline Repeatability</td>
<td>0.65 μm</td>
<td>4.85 μm</td>
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<td>Normalized $/Engine</td>
<td>0.64</td>
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Inquiries

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