NEAR KINEMATIC CONSTRAINT
Quasi-Kinematic (QKC) alignment

QKC characteristics:
- Arc contact
- Submicron repeatability
- Stiff, sealing contact
- Less expensive than KCs
- Easier to make than KCs

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

$F \text{ or } \Delta$

$\delta_{\text{initial}}$  $\delta = 0$  $\delta_{\text{final}}$

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Details of QKC element geometry

PAIRS OF QKC ELEMENTS

TYPE 2 GROOVE MFG.

CAST + FORM TOOL = FINISHED

ASSEMBLED JOINT

BOLT, BLOCK, BEDPLATE, PEG
Which variation of QKC to use

Design A + Design B

In Design A, Peg deforms on edge -> reduced repeatability
QKC methods vs kinematic method

Components and Definitions

- Cone Seat
- Relief
- Peg Surface

Force Diagrams

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Modeling QKC stiffness

Geometry - Material

Applied Loads [Fp & Mp]

Resultant Forces [n_i & F_i]

Deflections \( \delta \rightarrow \Delta r \)

Relative Error

Material

Contact Stiffness \( f_n(\delta_n) \)

Geometry

Displacements

QKC Model

Force/Torque

Stiffness
QKC contact mechanics

MECHANICS:

• Use Rotating Coordinate System
• Assume Sinusoidal Normal Distance of Approach
• Obtain Contact Stress Profile as Function of Above
• Integrate Stress Profile in Rotating CS thru contact

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Example: Duratec™ assembly

Characteristics:

• Ford 2.5 & 3.0 L V6
• > 300,000 Units / Year
• Cycle Time: < 30 s
Example: Assembly of Duratec™ block & bedplate

COMPONENTS

Block

Bedplate

ASSEMBLY

Assembly Bolts

C B Halves

Bedplate

Block

ERROR

δe MAX = 5 microns

Block Bore

Bedplate Bore
Bearing assemblies in engines

- Block
- Main Bearing Halves
- Crankshaft
- Piston
- Bedplate
- Block Main Bearing Half
- Bedplate Main Bearing Half
- Crank Shaft Journal
Detail of Duratec™ QKC element placement
Results of Duratec™ QKC Research

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>
<thead>
<tr>
<th>ITEM</th>
<th>QKC</th>
<th>Pinned Joints</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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<tr>
<td>Normalized $/Engine</td>
<td>0.64</td>
<td>1</td>
</tr>
</tbody>
</table>

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Engine assembly performance

QKC Error in Sensitive Direction

\[(\frac{\text{Range}}{2})_{\text{AVG}} = 0.65 \, \mu m\]

QKC Error in Axial Direction

\[(\frac{\text{Range}}{2}) = 1.35 \, \mu m\]