Design and Control of a Compact Ultra-Precision Machine for High Dynamic Performance
Why High-Dynamic Performance?

Ref: Fang et al., 2013

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What is a compact UP machine?

μ4 machine
What is the “problem”? “stiff frame”
What is the “problem”? “flexible frame”
What is the research hypothesis?

Improving position control of a linear stage based on real time measurements from array of accelerometers
What are the aims & objectives?

Capabilities:
• sub-micrometre accuracy
• high jerk (>500m/s³)

Aims:
• Machine modelling
• Technological solutions for improving control for “flexible frame”
What is the contribution?

**combining the apparent antagonistic requirements of a compact machine and high dynamic performance into one solution**
What is the methodology?

1. Problem definition
2. Analysis & Optimisation
3. Proof of concept

- System Identification
- Goals and requirements
- Sensors placement ↔ Mechanical design
- Control design
- Implementation
- Validation
What is the setup?

- Air bearing
- Slave side Air bearing
- Encoder
- Rail
- Frame
- Carriage
- Master side Air bearing
- Carriage

CAD

Test rig
System identification: methodology

Plate

Frame

Frame & guide-ways

Motion module
System identification: experimental equipment

Frame - “free-free” support

Motion module – operational measurements
System identification: modal measurements results
System identification:
correlation: FEM & modal measurements

Modal measurements – 459Hz

FEM – 473Hz
System identification:
correlation: FEM & modal measurements

Modal measurements – 459Hz

FEM – 473Hz
System identification:
correlation: FEM & modal measurements

Modal measurements – 593Hz
FEM – 647Hz
System identification: correlation: FEM & modal measurements

\[
y = 1.066x + 12.17, \text{ RMS}=0.9945
\]
System identification: control & modal measurements
What are the conclusions?

• Bottom-up system identification methodology was adopted

• System identification – different techniques showed a good correlation

• FEM-modal measurements correlation – input for mechanical design improvements

• Modal measurements analysis – input for control design
What’s next?

• Control techniques for “flexible frame”:
  Adaptive? Acceleration Feedforward / Feedback?

• Optimal sensor placement:
  Number, Location, Specification
Thank you