Precision Stages

HTSC Consortium Day
Eindhoven / November 18, 2016

Prof Dannis Brouwer
Prof Elena Lomonova
Goal

- Raise public / private interest
- Assess industrial needs
- Collaboration / Consortium creation
- Define topics
Agenda

- Intro
  - Part 1 by Dannis Brouwer
  - Part 2 by Elena Lomonova
- Fast forward session
  - Those who want to present 1 or 2 slides
- Open discussion
- Define topics
Dannis Brouwer:

- 1999-2001 2nd MSc Mechatronics, TU/e
- 2001-2004 Philips CFT (Center for Industrial Techn.)
- 2003-2007 PhD, University of Twente
- 2007-2012 Demcon Advanced Mechatronics
- 2007-2014 Assistant Prof, University of Twente
- 2014-2016 Associate Prof, University of Twente
- 2016- Prof, University of Twente
Precision Stages

1. Flexure systems
   for smooth and repeatable motion
2. Piezo-based actuation
   distribute actuation forces / reduce heat generation
3. Active and passive damping
   against internal vibrations
4. Vibration isolation
   against external disturbances
5. ?
Flexures for extreme stroke / stiffness / load
Challenge: Large range compliant mechanisms with sufficient accuracy
Preliminary result: high support stiffness over range of motion.
• Precision mechanisms:
  – More stiffness
  – Larger range of motion
  – Smaller size

• New applications:
  – Robotic mechanisms
  – Prostheses and Exoskeletons
  – Flexible implants
New approach I: Hybrid

Design Principles Insight

Parallel

Series
New approach II: Efficient models

Reduced non-linear mechanical models capturing only the relevant dynamics over range of motion are crucial.
New approach II: Efficient models

Reduced non-linear mechanical models capturing only the relevant dynamics over range of motion are crucial.
New approach III: Additive Manufacturing

Use geometric freedom of additive manufacturing
Topology optimization example

**ITERATION 1**

**PERFORMANCE**
- $f_{\text{par}}$: 0 Hz

**CONTRANTS**
- $\sigma_{\text{max}}$: 1288(600) MPa
- $M_{\text{max}}$: 4.3(2) Nm

- $d_{\text{of}}$: 17.1 [mm]
- $l_{\text{of}}$: 36.1 [mm]
- $l_{\text{is}}$: 0.44 [mm]
- $\theta_{\text{load}}$: 98.8 [deg]
- $\theta_{\text{of}}$: 129.2 [deg]

**FIGURE 8:** First parasitic frequencies of iteration 1, 3, 4, 6 and 8.
Topology optimization
SLS manufactured prototype

Optimal solution:
• Inner flexure: 6x FFRL
• Outer flexures: Double TFCH

Experimental validation:
• SLS manufactured prototype
• Material: Nylon
• Experimental results shows good agreement with the SPACAR models
Near future?
Possible application cases

- Ultra-fast precision stage to be used in the next generation lithography machines (ASML)
- An extremely stable and slow motion precision stage for a next generation TEM (Thermo Fischer))
- Flexure-based stage for extreme loads and range of motion (ASML)
- Articulated flexure-based vacuum compatible light weight robotic wafer handler (VDL ETG)
Piezo-based actuation to distribute actuation forces and reduce heat generation

- Control techniques to create low-stiffness behaviour of a stiff piezo actuator
- Mechanical techniques to reduce stiffness
- Control techniques providing a high level of actuator linearity.
Active and passive damping
against internal vibrations

- High Q-values / vacuum
- To damp peaks just outside the control bandwidth (stability)

- Constrained layer
- Tuned mass damper
- Active material
- In motion controller
<table>
<thead>
<tr>
<th>Interest industrial partners</th>
<th>Flexures</th>
<th>Piezo</th>
<th>Damping</th>
<th>ElectroM</th>
<th>PowerE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASM ALSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASML</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DÜRR Ecoclean/UCM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBS Precision Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innotron BV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mikrocentrum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI-Partners</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSD Animal Health</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nobleo Technology B.V.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTS group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermo Fisher Scientific</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM Profs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thank you for your attention