ITMO UNIVERSITY
DESIGN OF AN ADAPTIVE SYSTEM FOR STABILIZATION OF A LASER BEAM FOR CNC MACHINE
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Jyvaskyla, Finland
7-11 November 2016
INTRODUCTION

☑ Lasers have become a principal part of various amounts of technological equipment

☑ Adaptive optical stabilization systems are widely used in the numerous devices such as optical mounts, optical terminators, scanning tools, and many others

☑ There are a large number of papers dealing with the theoretical aspects of adaptive optical systems

☑ propose a new rigid optical stabilization system using the modified Stewart platform to compensate for the possible CNC tool shake
REVIEW OF EXISTING STABILIZATION SYSTEMS

- Shake compensating system
- Focusing mechanism
- Lens positioning system


D. Sachs, S. Nasiri, and D. Goehl, Image Stabilization Technology Overview. 3150A Coronado Drive, Santa Clara, CA 9505: InvenSense, Inc.
PROPOSED MECHANISM (KINEMATICS)

Modified Stewart platform kinematic scheme.
1 - motors, 2 - ball-screws, 3 - sliding shafts, 4 - hinges, 5 - link ball joints, 6 - moving platform, 7 - lens
PROPOSED MECHANISM (3D MODEL)

1 - motors
2 - sliding shafts
3 - hinges
4 - link ball joints
5 - moving platform
6 - lens
PLATFORM MOCK-UP
**Mock-up’s Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max height</td>
<td>100.5 mm</td>
</tr>
<tr>
<td>Min height</td>
<td>80.5 mm</td>
</tr>
<tr>
<td>Correction</td>
<td>22 mm</td>
</tr>
<tr>
<td>Max steps</td>
<td>6500</td>
</tr>
<tr>
<td>Steps per mm</td>
<td>365.17</td>
</tr>
<tr>
<td>Resolution</td>
<td>2.7 µm</td>
</tr>
</tbody>
</table>

Shafts lengths acceptable region
MATHEMATICAL MODEL

\[ \Delta \geq 0 \]
\[ S = \text{const} \]

\[ C = \frac{S}{2} - \frac{S}{2} \cdot \cos \gamma, \]
\[ H = \frac{(H - \Delta) + (H + \Delta)}{2} \]
\[ A^2 = (a + C)^2 + (H - \Delta)^2 \]
\[ B^2 = (a + C)^2 + (H + \Delta)^2 \]
\[ H - \Delta = \sqrt{A^2 - (a + C)^2} \]
\[ H + \Delta = \sqrt{B^2 - (a + C)^2} \]
\[ H = \sqrt{A^2 - \frac{(a + S/2 - S/2 \cos \gamma)^2}{2}} + \sqrt{B^2 - \frac{(a + S/2 - S/2 \cos \gamma)^2}{2}} \]

\( A \) and \( B \) - lengths of the two opposite drives, \( S \) - length of the moving platform, \( H \) - height of the moving platform
\[ \gamma = \pm \arccos \left( \frac{4a^2 + 8aC - 4aS' + 4C^2}{4S(a + C + S')} \right) - \left( \frac{4CS' + 4\Delta^2 - S^2 - S'^2}{4S(a + C + S')} \right) + 2\pi n, \, n \in \mathbb{Z} \]

\[ \Delta^2 = \left( \frac{S}{2} \right)^2 + \left( \frac{S' - 2(a + C)}{2} \right)^2 - 2 \cos \gamma \left( \frac{S}{2} \right) \left( \frac{S' - 2(a + C)}{2} \right) \]
MATHEMATICAL MODEL

Direction cosines

\[ e_x = \frac{a_x}{|\vec{a}|}; \quad e_y = \frac{a_y}{|\vec{a}|} \]

Euler’s unitary vector

\[ \vec{\Theta} = \begin{bmatrix} \theta_x \\ \theta_y \end{bmatrix} = \Theta \vec{e} = \begin{bmatrix} \theta_{e_x} \\ \theta_{e_y} \end{bmatrix} \]

Rotation vector

\[ \Theta = \begin{bmatrix} \theta_x \\ \theta_y \end{bmatrix} = 2\vec{e}\tan\frac{\theta}{2} = \begin{bmatrix} 2e_x \tan\frac{\theta}{2} \\ 2e_y \tan\frac{\theta}{2} \end{bmatrix} \]

Rodriguez-Hamilton parameters

\[ \lambda_0 = \cos\frac{\theta}{2} \]

\[ \lambda_1 = e_x \sin\frac{\theta}{2} \]

\[ \lambda_2 = e_y \sin\frac{\theta}{2} \]

\[ \lambda_0^2 + \lambda_1^2 + \lambda_2^2 = 1 \]
MATHEMATICAL MODEL

Quaternion with zero component

\[ \Lambda = \Lambda_0 + \vec{\Lambda} = \lambda_0 + \lambda_1 \vec{i} + \lambda_2 \vec{j} = \cos \frac{\theta}{2} + \vec{e} \sin \frac{\theta}{2} \]

Quaternion scalar part

\[ \Lambda_0 = \lambda_0 = \cos \frac{\theta}{2} \]

Quaternion vector part

\[ \vec{\Lambda} = \lambda_1 \vec{i} + \lambda_2 \vec{j} = \vec{e} \sin \frac{\theta}{2} \]

i and j are unit vectors of the moving frame

Rodriguez parameters

\[ \begin{align*}
2\dot{\lambda}_0 &= -\lambda_1 \omega_x - \lambda_2 \omega_y \\
2\dot{\lambda}_1 &= \lambda_0 \omega_x \\
2\dot{\lambda}_2 &= \lambda_0 \omega_y
\end{align*} \]

Euler’s unitary vector components orthogonal transformation matrix

\[ C_{i,j}^{x,y} = \begin{bmatrix}
\lambda_0^2 + \lambda_1^2 - \lambda_2^2 & 2\lambda_1 \lambda_2 \\
2\lambda_1 \lambda_2 & \lambda_0^2 + \lambda_2^2 - \lambda_1^2
\end{bmatrix} \]
Several designs of optical stabilization and focusing systems were reviewed.

A mathematical model of a beam stabilization system for CNC machine was studied.

Numerous existing designs of optical stabilization devices were considered to clarify the scope of the modelling problem. Their advantages and possibility of using them as part of a CNC machines were studied.

A large-scale stabilization system mock-up was built, and the acceptable region for sliding shafts was determined.
QUESTIONS?

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