ITMO UNIVERSITY

DESIGN OF AN ADAPTIVE SYSTEM FOR STABILIZATION OF A LASER BEAM FOR CNC MACHINE

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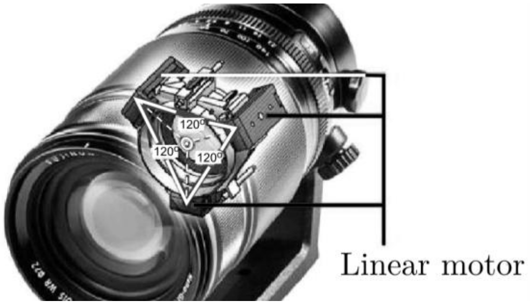
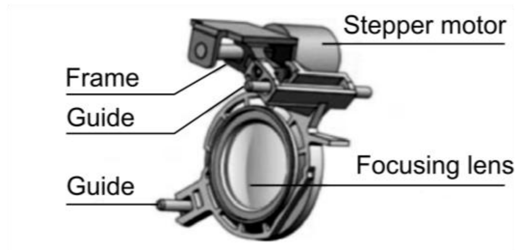
INTRODUCTION

- 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

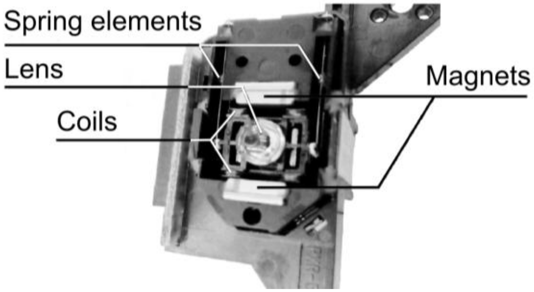
REVIEW OF EXISTING STABILIZATION SYSTEMS



Shake compensating system



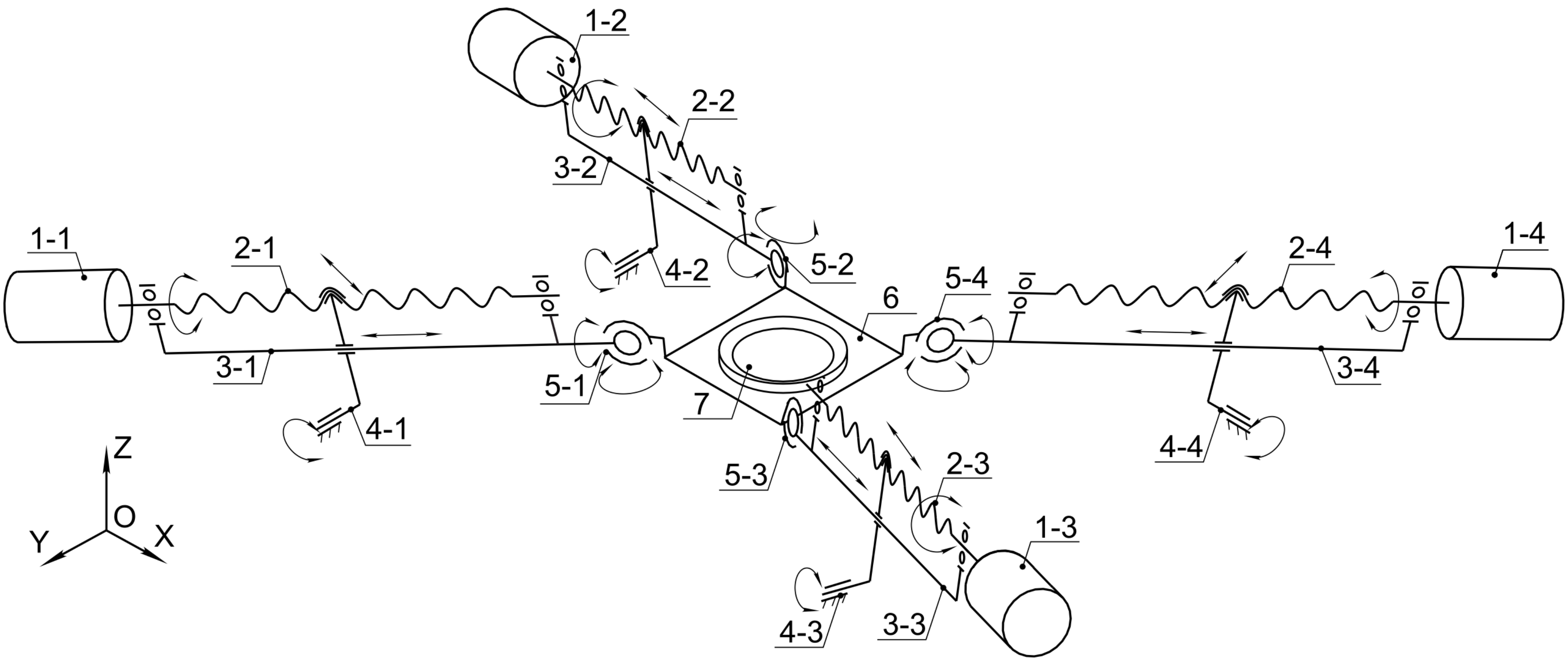
Focusing mechanism



Lens positioning system

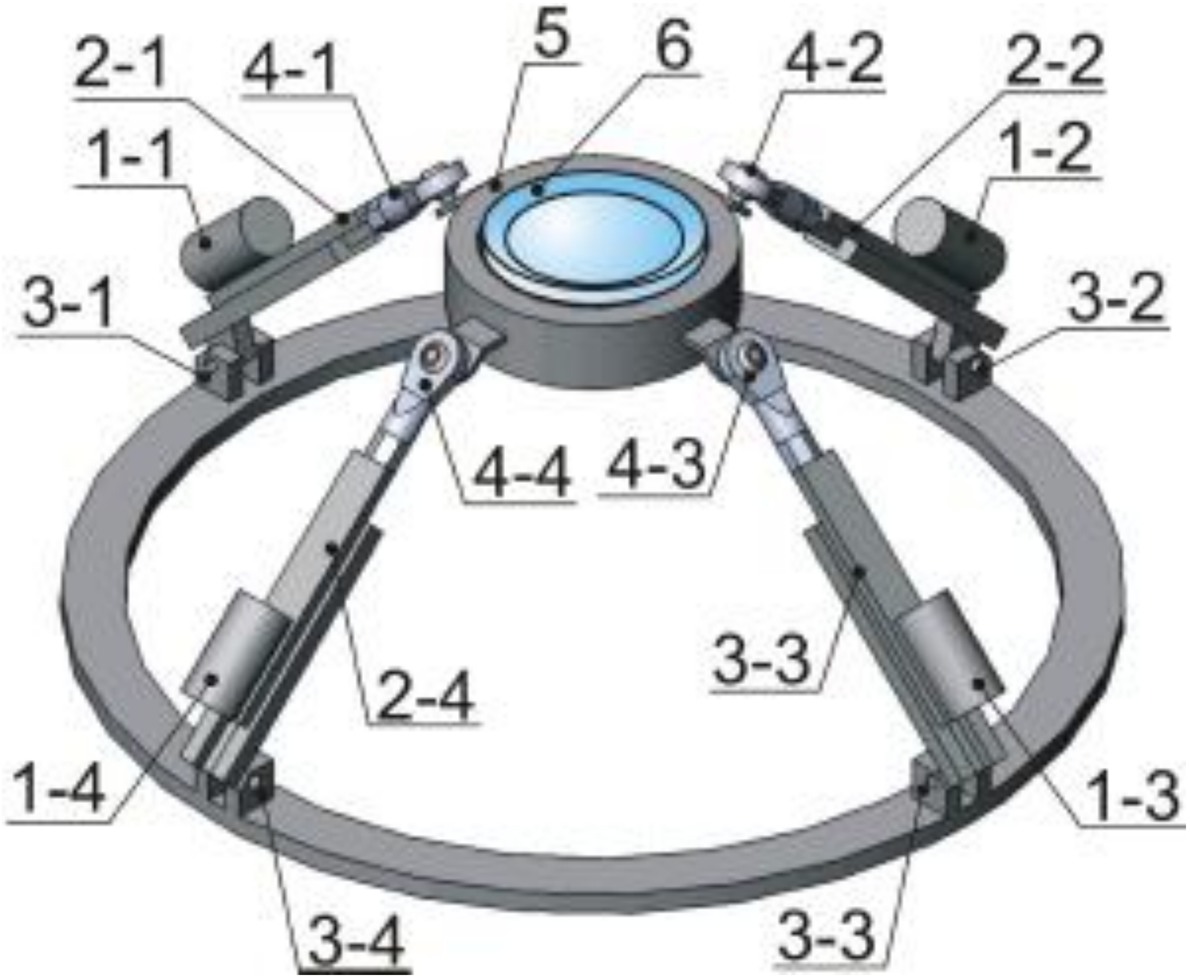
- C. Kim, M.-G. Song, N.-C. Park, K.-S. Park, Y.-P. Park, and D.-Y. Song, "Design of a hybrid optical image stabilization actuator to compensate for hand trembling," *Microsystem Technologies*, vol. 17, no. 5, pp. 971-981, 2011.
- J. Mayer, "Laser beam position control apparatus for a CNC laser equipped machine tool," U.S. Patent 6 528762, 04.03.2003.
- D. Sachs, S. Nasiri, and D. Goehl, Image Stabilization Technology Overview. 3150A Coronado Drive, Santa Clara, CA 9505: InvenSense, Inc.

PROPOSED MECHANISM (KINEMATICS)



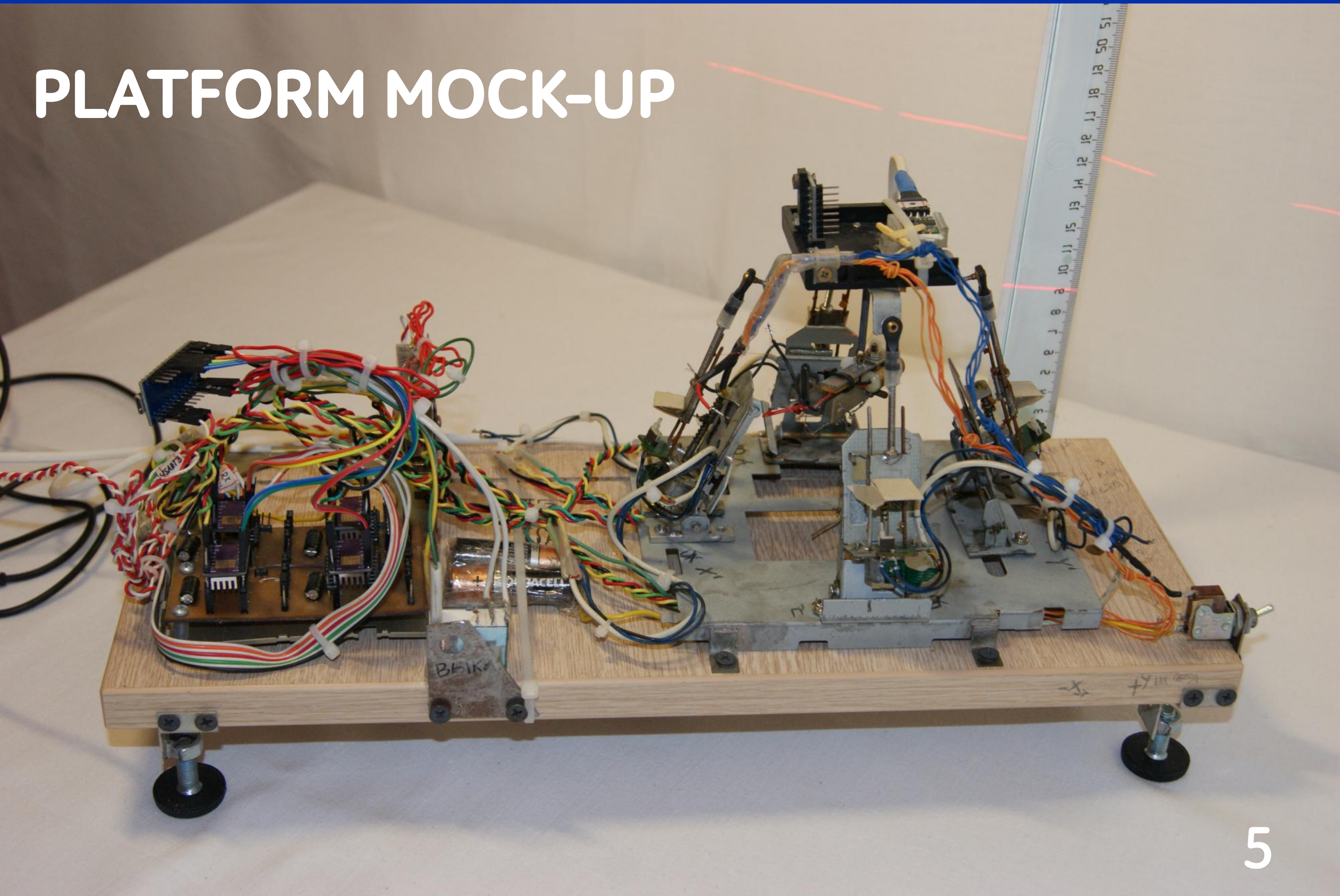
Modified Stewart platform kinematic scheme.
1 - motors, 2 - ball-screws, 3 - sliding shafts, 4 - hinges, 5 - link ball joints, 6 - moving platform, 7 - lens

PROPOSED MECHANISM (3D MODEL)

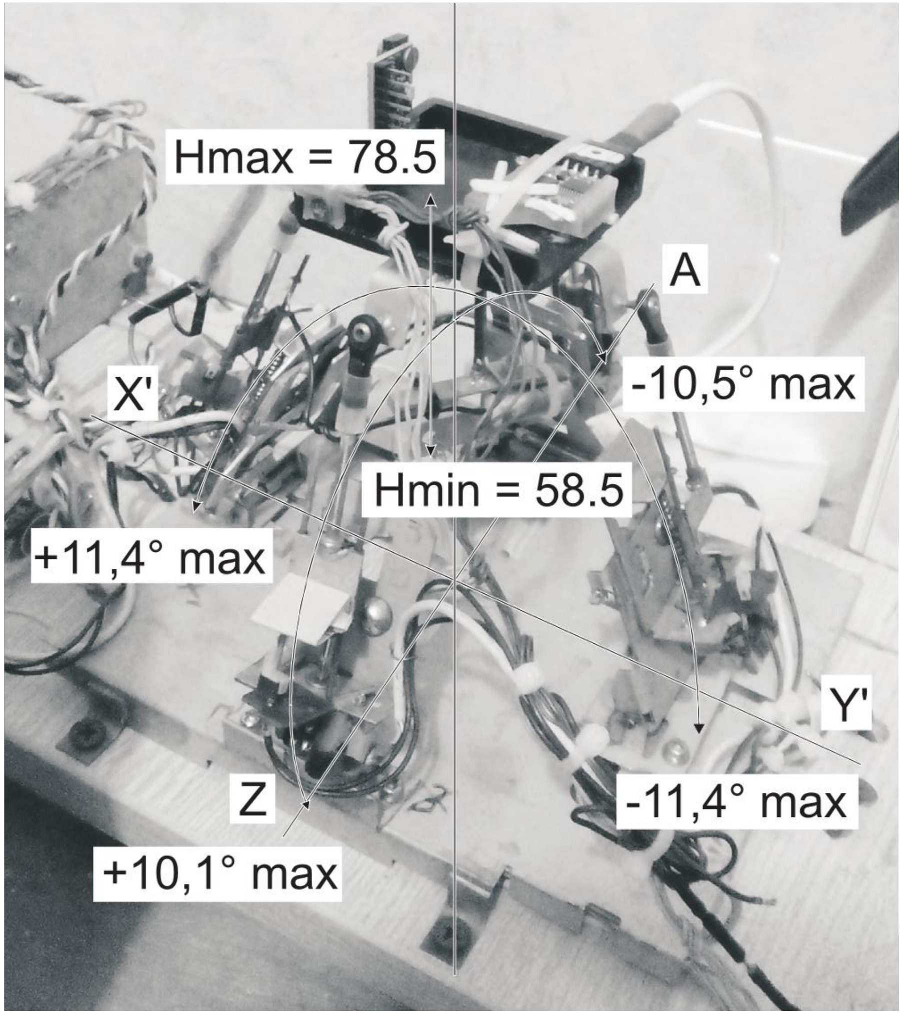


1 – motors
2 –sliding shafts
3 – hinges
4 – link ball joints
5 – moving platform
6 – lens

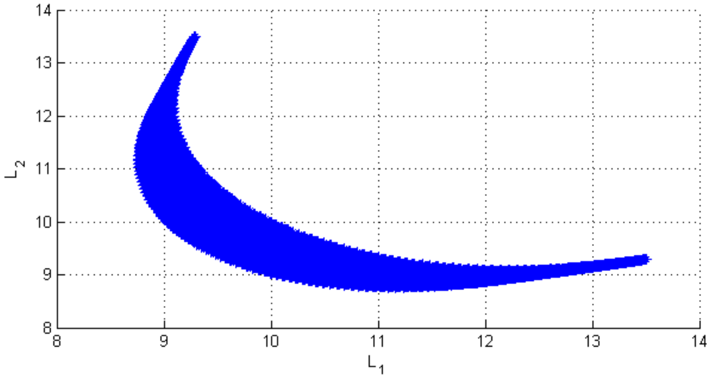
PLATFORM MOCK-UP



MOCK-UP'S PARAMETERS

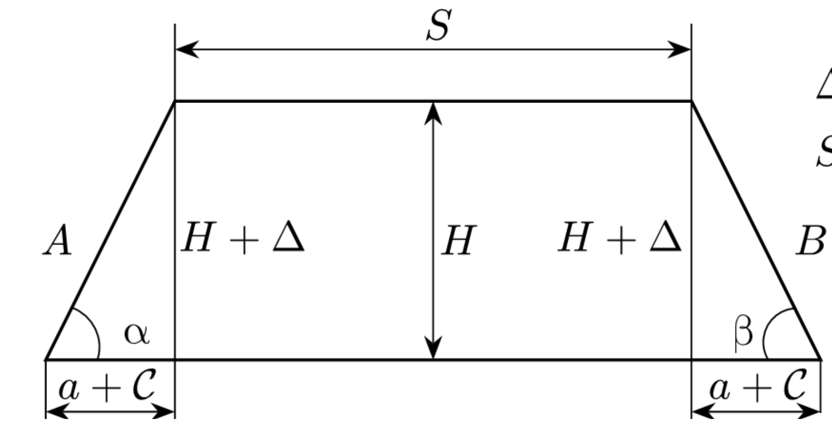


Parameter	Value
Max height	100.5 mm
Min height	80.5 mm
Correction	22 mm
Max steps	6500
Steps per mm	365.17
Resolution	2.7 μm



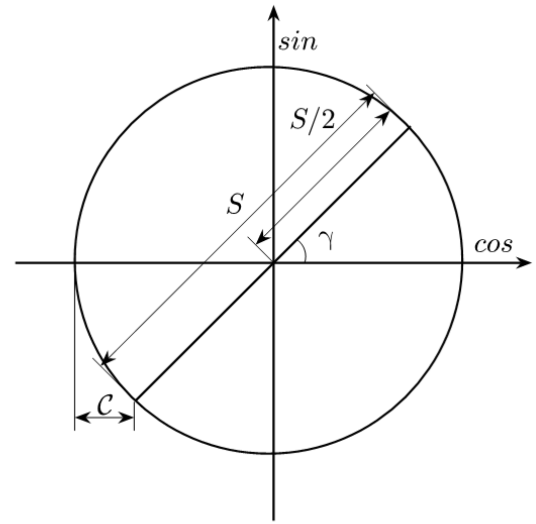
Shafts lengths acceptable region

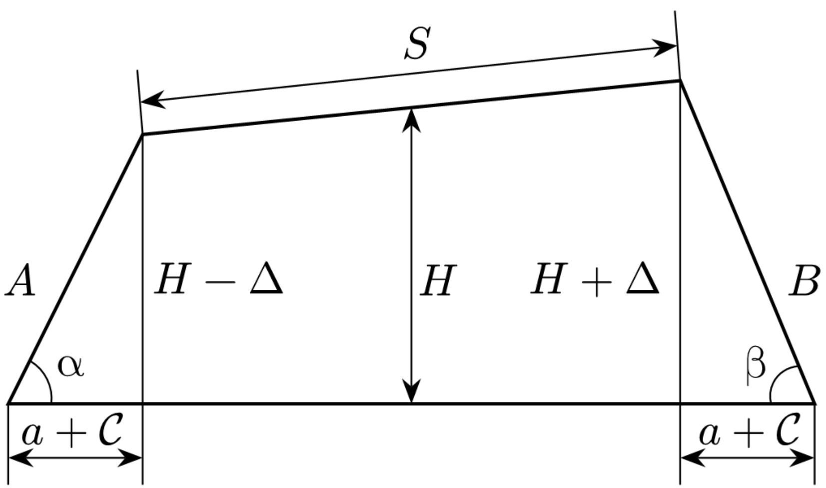
MATHEMATICAL MODEL



$$\Delta \geqslant 0$$

$$S = const$$





$$\mathcal{C} = \frac{S}{2} - \frac{S}{2} \cdot \cos\gamma,$$

$$H = \frac{(H-\Delta)+(H+\Delta)}{2}$$

$$A^2 = (a+\mathcal{C})^2 + (H-\Delta)^2$$

$$B^2 = (a+\mathcal{C})^2 + (H+\Delta)^2$$

$$H-\Delta = \sqrt{A^2-(a+\mathcal{C})^2}$$

$$H+\Delta = \sqrt{B^2-(a+\mathcal{C})^2}$$

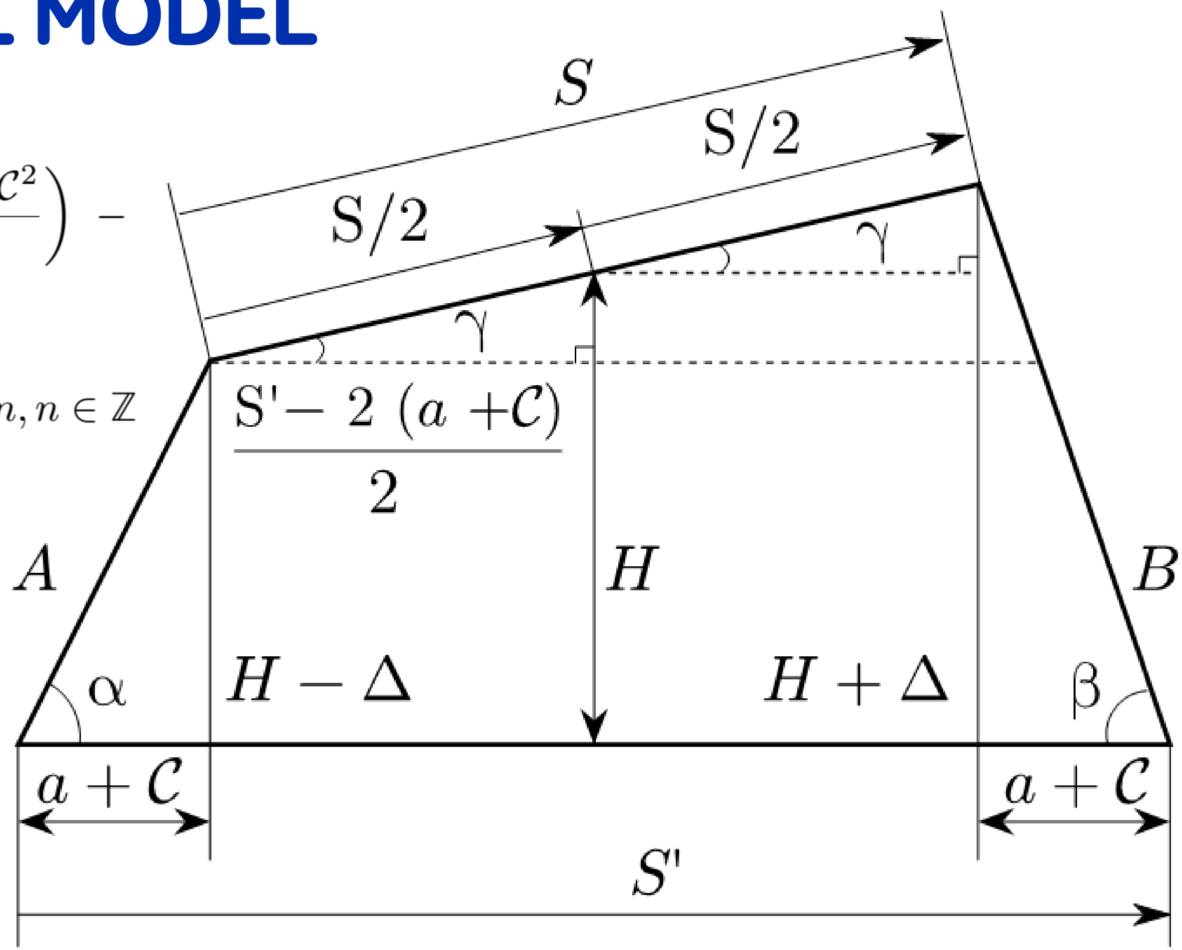
$$H = \frac{\sqrt{A^2-(a+{}^{S}\!/_{2}-{}^{S}\!/_{2}\cos\gamma)^2}}{2} +$$

$$+\frac{\sqrt{B^2-(a+{}^{S}\!/_{2}-{}^{S}\!/_{2}\cos\gamma)^2}}{2}$$

A and *B* - lengths of the two opposite drives, *S* - length of the moving platform, *H* - height of the moving platform

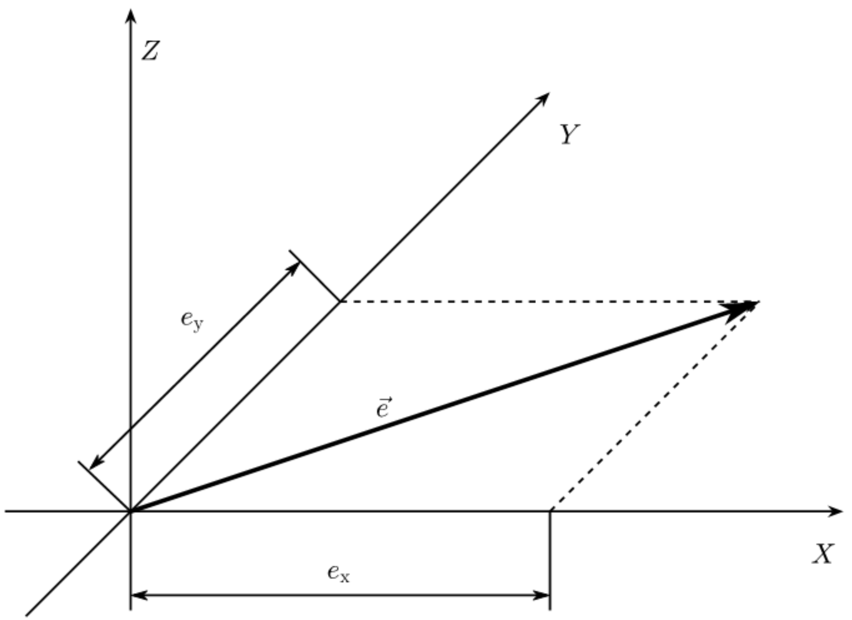
MATHEMATICAL MODEL

$$\gamma = \pm \arccos\left[\left(\frac{4a^2 + 8a\mathcal{C} - 4aS' + 4\mathcal{C}^2}{4S(a+\mathcal{C}+S')}\right) - \left(\frac{4\mathcal{C}S' + 4\Delta^2 - S^2 - S'^2}{4S(a+\mathcal{C}+S')}\right)\right] + 2\pi n, n \in \mathbb{Z}$$



$$\Delta^2 = \left(\frac{S}{2}\right)^2 + \left(\frac{S' - 2(a+\mathcal{C})}{2}\right)^2 - 2\cos\gamma \left(\frac{S}{2}\right)\left(\frac{S' - 2(a+\mathcal{C})}{2}\right)$$

MATHEMATICAL MODEL



Direction cosines

$$e_x = \frac{a_x}{|\bar{a}|}; \qquad e_y = \frac{a_y}{|\bar{a}|}$$

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

$$\boldsymbol{\Theta} = \begin{bmatrix} \theta_x \\ \\ \theta_y \end{bmatrix} = 2\vec{e}\tan\frac{\theta}{2} = \begin{bmatrix} 2e_x \tan{}^{\theta}/_{2} \\ \\ 2e_y \tan{}^{\theta}/_{2} \end{bmatrix}$$

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

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

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

$$\begin{cases} 2\dot{\lambda}_0 = -\lambda_1\omega_x - \lambda_2\omega_y \\ 2\dot{\lambda}_1 = \lambda_0\omega_x \\ 2\dot{\lambda}_2 = \lambda_0\omega_y \end{cases}$$

Euler's unitary vector components orthogonal transformation matrix

$$C_{i,j}^{x,y} = \begin{bmatrix} \lambda_0^2 + \lambda_1^2 - \lambda_2^2 & 2\lambda_1\lambda_2 \\ 2\lambda_1\lambda_2 & \lambda_0^2 + \lambda_2^2 - \lambda_1^2 \end{bmatrix}$$

CONCLUSION

- 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

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QUESTIONS?

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