MICRO-NANO SYSTEM USED FOR PROBE POSITONING WITH NANOMETRIC PRECISION UNDER AFM MICROSCOPE

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***Abstract**: Although atomic force microscope is an ultra-modern equipment, to use it at full capacity we need to find a method to handle the sample at nanometer level. This means in addition to translational motion that can be achieved on a microscope we need to design a device who can rotate the sample on all axes.*

***Keywords:** atomic force microscope, hexapod system, nanometric precision*

1. INTRODUCTION

Atomic force microscope is a tool that can describe the surface topography, using a peak surface interaction analysis. The tip is attached to a flexible blade and its movement is recorded by an optical device. When the tip is near the surface, it is subjected to the action of two opposing forces: A force of attraction: Van der Waals and a repulsive force of an electrical nature. The sample is placed on a surface of a piezoelectric engine who has freedom of movement in all directions. At horizontal displacement of the engine, the tip finds balance as far from the surface, thus describing the sample topography. The tips are generally made from diamonds, tungsten and SiO2 and they have a radius of curvature 100-150nm. They also allow a much higher measurement resolution than is obtained with profilometry technique. Dependence on distance as Van der Waals forces is of type $1/d^2$ for a spherical geometry implies a peak and a flat surface can be obtained lateral resolution ranging around 1nm. To increase resolution device, must work on a very small distance between the tip and surface in the region where the forces of rejection are dominant.
Although atomic force microscope is an ultra-modern equipment, to use it at full capacity we need to find a method to handle the sample at nanometer level, This means in addition to translational motion that can be achieved on a microscope we need to design a device who can rotate the sample on all axes.
For precise handling of small samples is needed a nanometer, robust system which can give our necessary stability.
This system was designed and simulated from two equipments :
1. A nano- positioning system (F206)

2. A mini gripper for precise handling of the sample under microscope

The F-206.S HexAlign Hexapod is a highly accurate micropositioning system for complex multi-axis alignment tasks. It is based on PI"s long experience with ultra-high-resolution, parallel kinematics stages. Unlike hexapods with variable-length struts ("legs") the F-206 features constant-length struts and friction-free flexure guides. This gives the F-206 even higher precision than other hexapod designs.

The F-206.S, Six-Axis Hexapod Alignment System from Nanopositioning Specialist PI the most affordable precision positioning system of its kind. It provides 6D motion with 33 nanometer resolution and advanced alignment software for optics and photonics components
And the gripper characteristics are :
Stroke: 0.2 mm
Resolution: 1 nm
Gripping force: 10 mN
Diameter of cannula: 0.8 mm

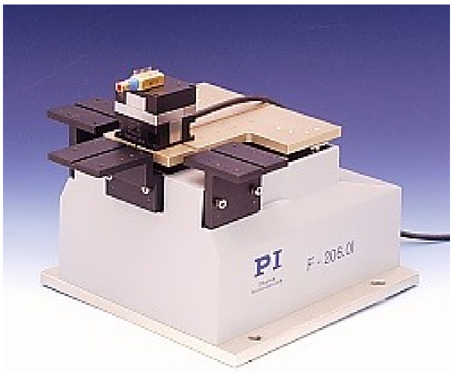

Fig.1. F.206 Hexapod used in simulation

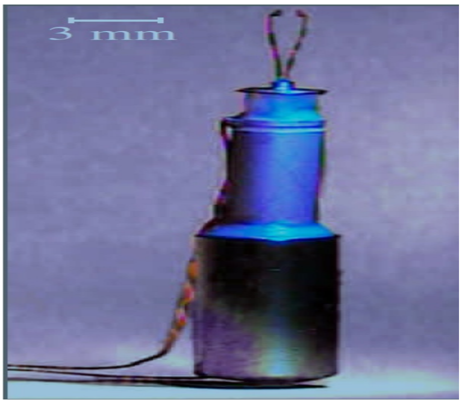

Fig. 2. Canulla gripper used in simulation

2. HEXAPODAL MATHEMATICAL MODELATION

Based on the structure and kinematics positioning system that is the hexapod , there were calculated leg lengths necessary to reach the desired spatial position (position and inclination)
In order to define the platform positon the next parameters are user: coordinates x, y, z of the center platform and to define the orientation, three independent angles (Euler angles)
ψ- rotation around the vertical axis
θ- tilting platform in horizontal axis
φ- Platform rotation about the axis passing through the center and is perpendicular to it

For a given point P we have the following relations between coordinate systems $O_0\ X_0Y\ _0Z_0$ si $O_1\ X_1Y\ _1Z_1$

$V_P^0=[V_{01}^0]+[\psi_1^0]*[\theta_1^0]*[\varphi_1^0]*[V_P^1]$ (1)

As input dates will be the position (X,Y,Z) , and the angles (ψ, θ, φ)
The output data will be distances of the 6 legs of the hexapod

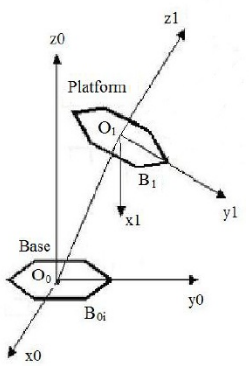

Fig.3. Classical structure of a hexapod

$V_{dest}=(X\ Y\ Z)$ (2)

$$\psi=\begin{pmatrix}\cos(\psi) & \sin(\psi) & 0\\ -\sin(\psi) & \cos(\psi) & 0\\ 0 & 0 & 1\end{pmatrix} \quad (3)$$

$$\theta=\begin{pmatrix}\cos(\theta) & 0 & -\sin(\theta)\\ 0 & 1 & 0\\ \sin(\theta) & 0 & \cos(\theta)\end{pmatrix} \quad (4)$$

$$\varphi=\begin{pmatrix}\cos(\varphi) & \sin(\varphi) & 0\\ -\sin(\varphi) & \cos(\varphi) & 0\\ 0 & 0 & 1\end{pmatrix} \quad (5)$$

$A1= V_{dest} + \psi* \theta* \varphi*V_{p11}$ (6)
$A2= V_{dest} + \psi* \theta* \varphi*V_{p12}$ (7)
$A3= V_{dest} + \psi* \theta* \varphi*V_{p13}$ (8)
$A4= V_{dest} + \psi* \theta* \varphi*V_{p14}$ (9)
$A5= V_{dest} + \psi* \theta* \varphi*V_{p15}$ (10)
$A6= V_{dest} + \psi* \theta* \varphi*V_{p16}$ (11)
V_{p1n} - represents the initial position of the leg in the base system (XYZ)

and further we calculated the distances required to achieve the desired leg to the desired orientation

$dist_1=$
$$\sqrt{(Vp_{1,1}(1)-A1(1))^2+(Vp_{1,1}(2)-A1(2))^2+(Vp_{1,1}(3)-A1(3))^2} \quad (12)$$
$dist_2=$
$$\sqrt{(Vp_{1,2}(1)-A2(1))^2+(Vp_{1,2}(2)-A2(2))^2+(Vp_{1,2}(3)-A2(3))^2} \quad (13)$$
$dist_3=$
$$\sqrt{(Vp_{1,3}(1)-A3(1))^2+(Vp_{1,3}(2)-A3(2))^2+(Vp_{1,3}(3)-A3(3))^2} \quad (14)$$
$dist_4=$
$$\sqrt{(Vp_{1,4}(1)-A4(1))^2+(Vp_{1,4}(2)-A4(2))^2+(Vp_{1,4}(3)-A4(3))^2} \quad (15)$$
$dist_5=$
$$\sqrt{(Vp_{1,5}(1)-A5(1))^2+(Vp_{1,5}(2)-A5(2))^2+(Vp_{1,5}(3)-A5(3))^2} \quad (16)$$
$dist_6=$
$$\sqrt{(Vp_{1,6}(1)-A6(1))^2+(Vp_{1,6}(2)-A6(2))^2+(Vp_{1,6}(3)-A6(3))^2} \quad (17)$$

3. HEXAPODAL SIMULATION IN MATLAB ENVIRONMENT

Positioning system was then designed in SolidWorks and then imported into Matlab for kinematics modeling. In Matlab we used for modelation the SimMechanics module from the SimScape library. Each joint, each element was calculated therefore the result was a graphical simulation
SimMechanics provides a multibody simulation environment for 3D mechanical systems, such as robots, vehicle suspensions, construction equipment, and aircraft landing gear. You model the multibody system using blocks representing bodies, joints, constraints, and force elements, and then SimMechanics formulates and solves the equations of motion for the complete mechanical system. Models from CAD systems, including mass, inertia, joint, constraint, and 3D geometry, can be imported into SimMechanics. An automatically generated 3D animation lets you visualize the system dynamics.

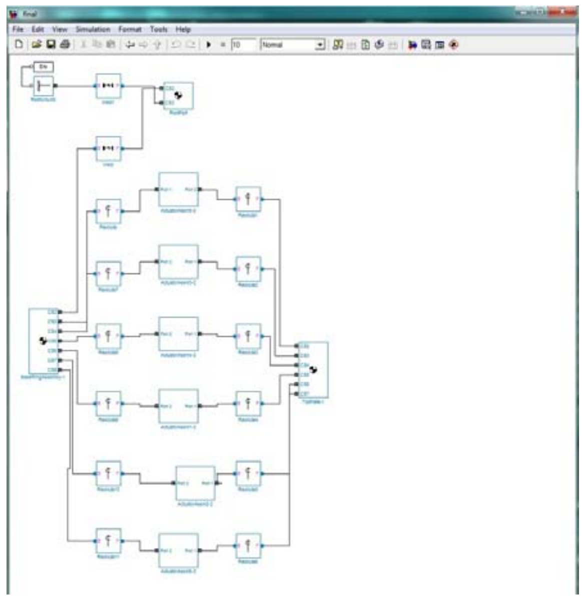

Fig.4. Matlab simulation software developed for the system

4.CONCLUSIONS

The system designed from the following subsystems: atomic force microscope (AFM), positioning system with 6 degrees of freedom and micro nano gripper can assure manipulation on a nano level for a probe in order to examine under microscope. According to simulations performed in Matlab, the positioning system can respond to commands to reach a certain point at a certain pitch you want.

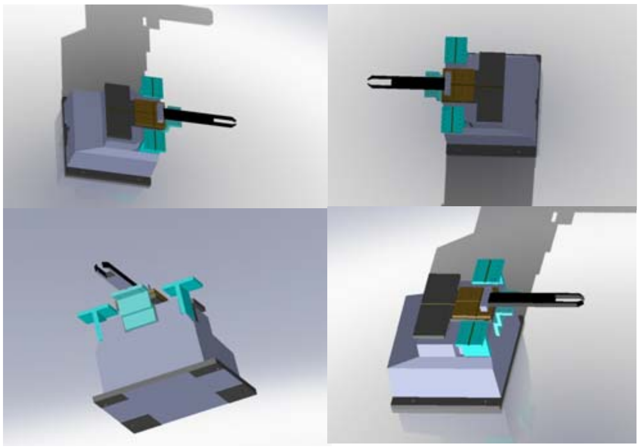

Fig.5. The system for positioning simulated in Matlab

The application in which we consider using this device are : alignment & testing of optics, Nanolithography, semiconductor handling / test system, Collimator and fiber bundle alignment.
The system has proven to be an ideal platform for this application considering:

- High precision
- Six-axis functionality
- Freely software-settable rotational pivot point
- Integrated high-speed metrology
- Compact footprint
- Broad suite of fully-integrated, high-speed automated-alignment routines
- Comprehensive, industrial-class supporting software, including LabVIEW libraries, and COM-compliant 32-bit DLLs.

5.REFFERENCES

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