

DEVELOPMENT OF A MINIATURE ADJUSTING DEVICE SCULPTED INTO A PARALLEL LINKAGE

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1. Introduction

Recently, sensor units and machine elements are miniaturized into the size of less than several millimetres in order to downsize machines and equipments; and also, the sensor units and the machine elements are produced into ultra precise dimensions and with high quality materials in order to detect signal sensitively and to accomplish delicate functions. Therefore, it is necessary to adjust positions and postures of these miniature parts finely; and it is necessary to fix these miniature parts on the equipments at their ideal positions and ideal postures firmly; and it is necessary to hold positions and postures of these miniature parts on the equipments permanently. If the miniature parts are not adjusted accurately and are not fixed on the equipments firmly, and are not held in their position and posture lastingly, their abilities are not realized sufficiently.

Several systems to adjust position and posture for a component, and to fix the component on the equipment, and to hold its position and posture were developed.

Firstly, the system of fits is mentioned, in which the component is inserted into a groove of the equipment. Accuracy of the positioning and the posturing in the system is always settled into fit tolerance. The component is easily adjusted without troublesome operations if the fit tolerance is smaller than acceptable error for assembling the component and the equipment, and the component is usually fixed by bolts and so on. However, it is impossible to adjust the position and the posture of the component into the acceptable error if its value is less than several micro-metres. If the excessive force acts to the component, or if the bolts are loose, the component is slid within a width clearance between the components and the groove. The component is not positioned and is not postured definitely.

Secondly, the system of a dowel is mentioned, in which a cylindrical pin or a shoulder-bolt is inserted into a reamed hole bored through the component and the equipment. The reamed hole is made in one boring process after the components is finely adjusted and is temporarily fixed to the equipment by the bolts. Accuracy of the positioning and the posturing in the system are settled into the adjusting error and a temporary fixing error. Although a lot of troublesome operations are required for the adjustment, the component is permanently held its position and its posture. However, it is impossible to bore the reamed hole without deviation of several micro-metres because cutting force for drilling and reaming is occurred vibrations and deformations of the component. Even if the reamed hole is bored at the adjusted point accurately, a lot of chips are scattered around the component.

Thirdly, the system of adjusting stages is mentioned, in which the component is fixed on the top of the stage and its position and its posture are adjusted by rotating of control screws. Accuracy of the positioning and the posturing in the system are settled into the adjusting error, backlash, and stiffness error. The component is finely adjusted toward six directions of x , y , z , θ_x , θ_y and θ_z . However, it is difficult to hold the position and the posture permanently because the elements of the stage are wobbled in the backlash and the stiffness of the stage consisting of small elements is not raised higher. Moreover, if the system is used, advantages of the miniaturized parts are lost entirely because the stage becomes much bigger than the component.

A novel miniature device for adjusting, fixing and holding the miniature parts is thought up in this paper. The device can easily adjust the positions and the postures toward six directions of x , y , z , θ_x , θ_y and θ_z . The device is monolithically sculpted into a parallel linkage. The stiffness is strongly. The device is held in the position and the posture permanently.

2. Structure of the miniature adjusting device

The miniature adjusting device consists of an top plate, a bottom plate, and six elastic hinge frames arranged between the top plate and the bottom plate as shown in figure 1 and figure 2. These parts are sculpted in a small hexagonal prism like an openwork, and the device composes a seamless parallel linkage in which the elastic hinge frames are connected to the top plate and the bottom plate with universal flexure hinge joints. The elastic hinge frames are individually extended or are individually shrunk, and the top plate is adjusted into a reference position (i.e., x , y , z) and a reference attitude (i.e., θ_x , θ_y and θ_z).

The miniature adjusting device was made of aluminum alloy. A side of the hexagonal prism was forty millimeters and its height was fifty millimeters.

3. Structure of the elastic hinge frames

In the parallel linkage, if a movable range for the top plate is required widely, the elastic hinge frames must be extended widely and must be shrunk widely; besides, joint of the elastic hinge must be bend to any directions flexibly. Therefore, the elastic hinge frame is formed in the special shapes.

The elastic hinge frame consists of an elastic hinge plate, a turnbuckle, and two binding frames as shown in figure 3. Shape of the elastic hinge plate is the shape in which four quarter circles are connected inversely. The turnbuckle is inserted between horizontal edges, and the elastic hinge plate is extended, or is shrunk by rotating the turnbuckle. As the elastic hinge plate is inserted in two binding frames, the quarter circle is deformed along the ditch composed by the binding frame A

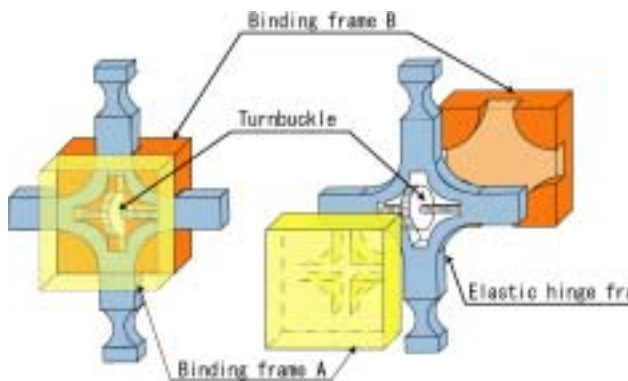


Figure 3. Structure of the elastic hinge frame

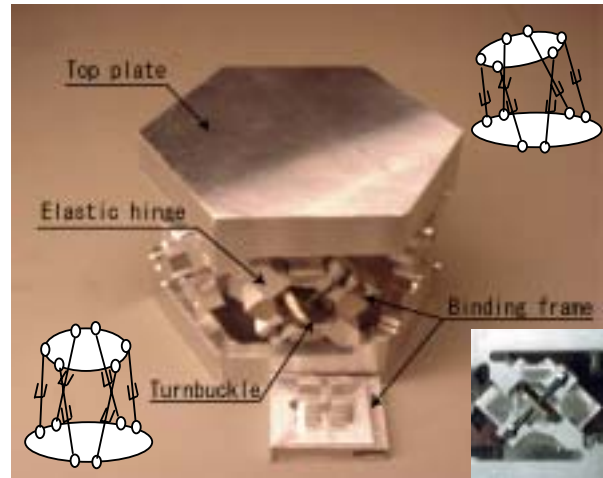


Figure 1. The miniature adjusting device sculpted into a parallel linkage

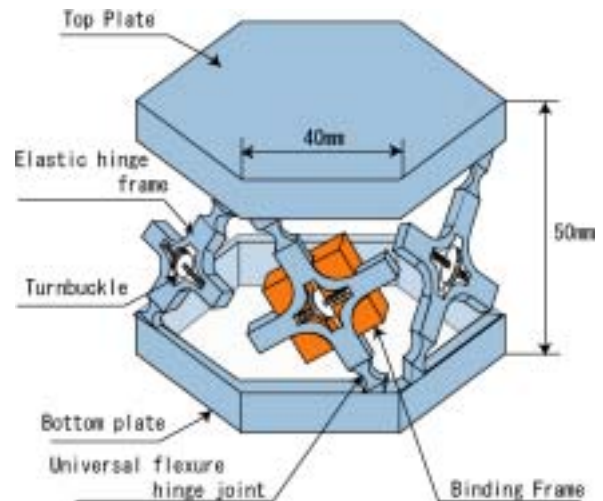


Figure 2. Structure of the miniature adjusting device

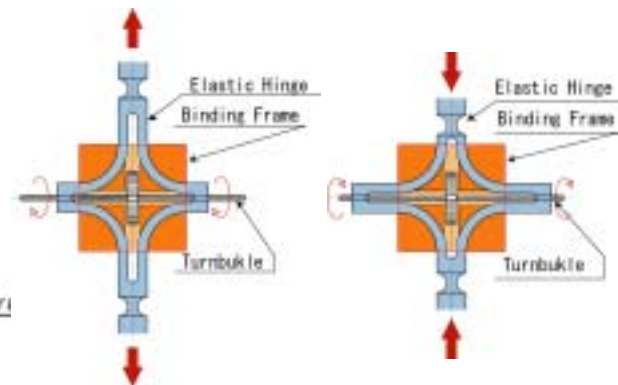


Figure 4. Deformation of the elastic hinge plate

and B. If the quarter circle is thin, the quarter circle is slid with a little resistance force, so the elastic hinge plate is extended widely and is shrunk widely as shown in figure 4. However, stiffness of the elastic frame is high because two binding frames limited the deformation of the quarter circle.

Thickness of the quarter circle was 0.5 millimeters. Radius of the quarter circle is 5 millimeters.

3. Experimental Results

In the experiments, attitudes and positions of the miniature adjusting device were measured when the turnbuckles rotated several times clockwise or counterclockwise, and stiffness of the elastic hinge frame was also measured when the binding frame fit to the elastic hinge plate or does not fit to elastic hinge plate.

The displacements at six edge of the top plate were measured under the coordinate frame shown in figure 5. Figure 6-(1) shows the displacement of z direction, that is a height displacement, when the turnbuckles of six elastic hinges were rotated until quarter one after another. When turnbuckles were rotated, the height displacement is nearly same. The figure is graphed conveniently. Figure 6-(2) shows the location of the six edge of the top plate into the x-y plane when 1 turnbuckles of hinge 1, hinge 3 and hinge 5 were rotated until quarter. The figure is graphed conveniently. The top plate was rotated about 0.14 degrees.

The stiffness of the elastic hinge frame with fitting the binding frames or without fitting the binding frames was calculated by measuring width and height of the elastic hinge frame under loading force as shown in the figure 7. Figure 8 shows the horizontal displacement, that means the width displacement, and the vertical displacement, that means height displacement, against the rotations of the turnbuckle. Figure 9 shows the relationship between the vertical displacement and horizontal displacement. When the turnbuckle was rotated once, that means 360 degrees, width of the elastic hinge frame was reduced 0.25 millimeters which correspond to the screw pitch of 0.25 millimeters, and height of the elastic hinge frame was extended 0.1 millimeters.

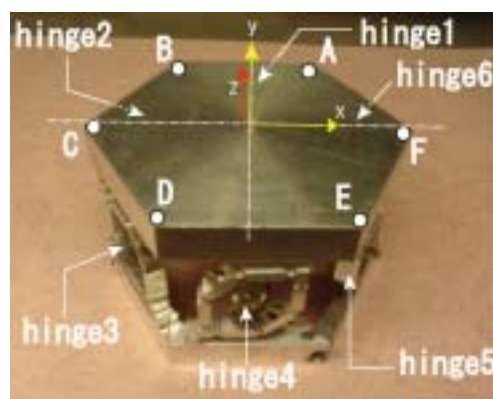


Figure 5. Coordinate frame for experiments

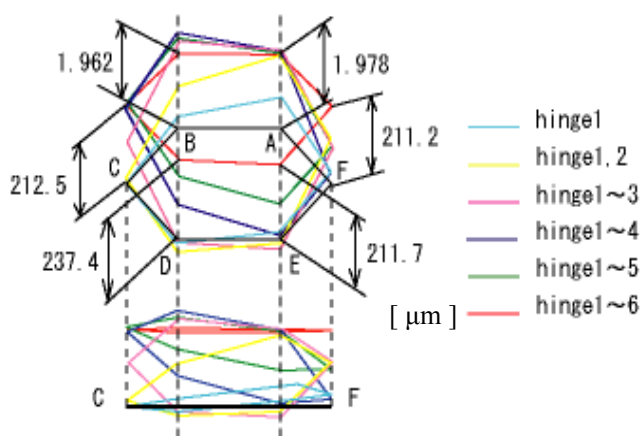
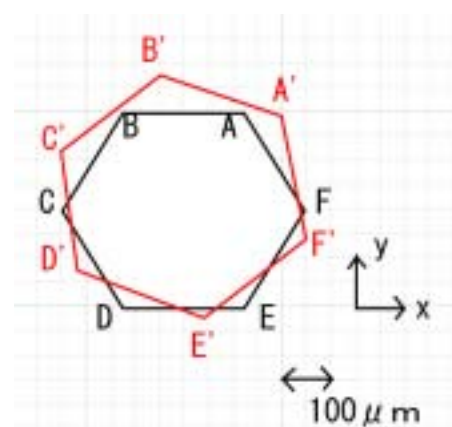


Figure 6-(1) Experimental result (1)



[Location by rotating of turnbuckles of 1,3,5]

Figure 6-(2). Experimental result (2)

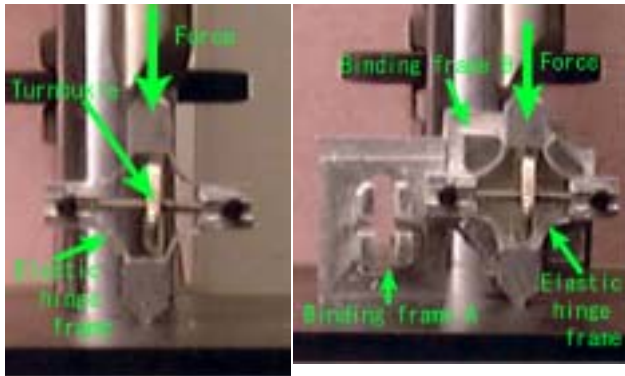


Figure 7. Stiffness experiment with the binding frame and without the binding frame

Figure 10 shows a vertical stiffness and a horizontal stiffness of the elastic hinge frame. The vertical stiffness was calculated by dividing loading force by the vertical displacement, where the compressive stiffness was expressed by a negative number and tensile stiffness was expressed by a positive number. The horizontal stiffness was calculated by dividing loading force by the vertical displacement.

The stiffness of the elastic hinge frame with the binding frames was much higher than the stiffness of the elastic hinge frame without the binding frames.

6. Conclusions

The miniature adjusting device sculpted into a parallel linkage was developed. The device could easily adjust the positions and the postures toward six directions of x , y , z , θ_x , θ_y and θ_z . The stiffness of the elastic hinge frame with the binding frames was strong.

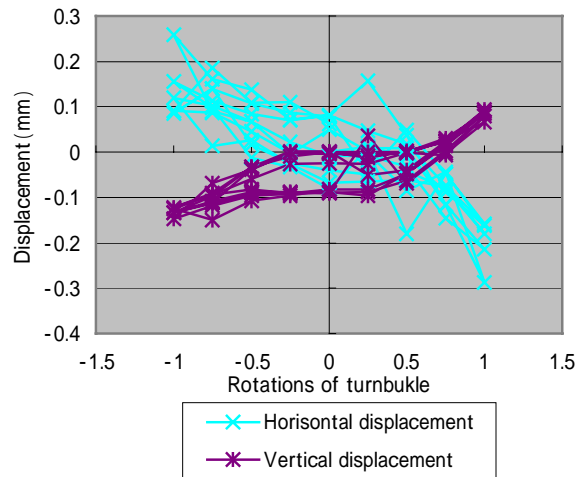


Figure 8 Horizontal and vertical displacement of the elastic hinge frame against the rotations of the turnbuckle

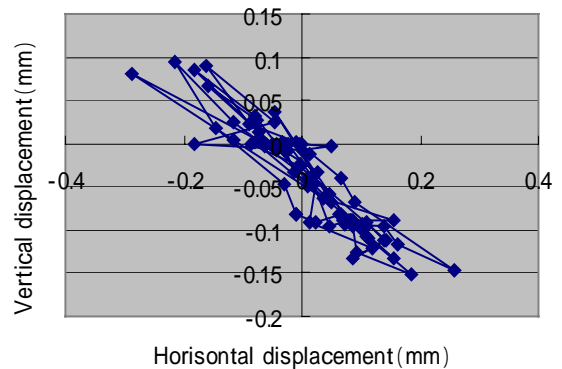


Figure 9 Relationship between vertical and horizontal displacements

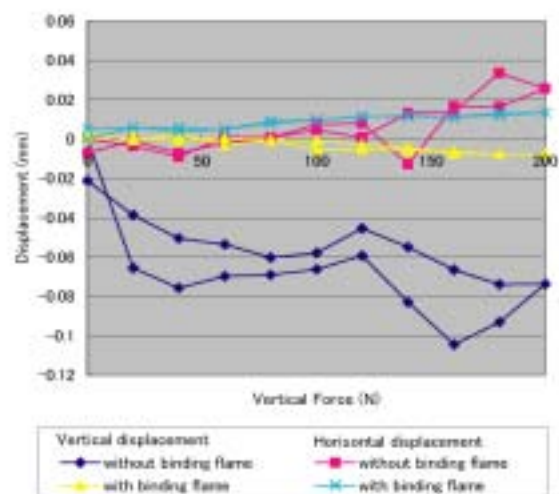


Figure 10 Stiffness of the elastic hinge frame