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Topological Design and Analysis of Micro Grasping Device

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Abstract- The design of monolithic- compliant based micro grasping mechanism achieving a greater geometrical advantage is a challenging task of the designer working in the area of micro devices. The monolithic design of micro grasping device is developed by adopting the topological optimization technique using the mathematical tool, MATLAB. The developed design is further subjected to post optimization in order to reduce the localized stress concentration at the hinge locations. The flexure hinges are introduced in the post optimization stage in view of reducing the complexity of manufacturing the micro grasping device. Finite Element Method (FEM) is explicitly used to study the performance of the micro grasping device by checking its structural integrity by finding the amount of displacement and the induced stress levels during the real time applications. The FE analysis results of the micro grasping device shows that the proposed design has the greater geometrical advantage compared to the other designs found in the literatures in addition to the simplicity in manufacturing aspect of the device.

Index Terms- Compliant mechanism, FEM, Flexure hinges, Monolithic, Topological optimization.

1. INTRODUCTION

Handling a micro sized components with high precision motion control is a challenging task in the process of micro assembly. Micro gripper or micro grasping device plays a predominant role in manipulating the micro sized parts. Developing the design for suitable mechanism and achieving the desired motion of the grasping devices are another important task to obtain a précised and controlled motion. The design of such devices needs to be trouble-free in fabrication. Hence the design should be less complexity in geometry and monolithic part. Mechanism design can be obtained by intuitively or traditional kinematic synthesis or topological optimization technique. Among the other methods, topological optimization is the best way to obtain a compliant mechanism. MATLAB code has been developed to optimize the design domain of the micro grasping device topologically. Solid Isotropic Material Penalization (SIMP) algorithm is used to optimize the micro grasping device, because of its simplicity [1].

The topological design obtained is then subjected to post optimization to integrate the flexure at the positions where single node contact created between elements [2]. Many researchers used other methods like kinematic linkage model [3], intuitively [4] and pseudo rigid body model [5, 6] to design the micro grasping device.

In this research work, an attempt is made to develop the topologically optimized design of a new micro grasping device based on the compliant mechanism concepts for the MEMS applications. The design of the proposed compliant micro grasping device has two jaws; one is moving and the other refers to be fixed. Being one jaw of the grasping device is fixed, the percentage of positioning error is reduced, high precision in positioning are achieved, stability, repeatability and life of the component also increased. But the geometrical advantage is not being sacrificed. This design gives the significant value of geometrical advantage. The design of moving jaw of the micro grasping device is attained from the MATLAB code. Structural analysis of the design is carried out in FEM software to obtain the deformation and stress levels [9] in order to predict its behavior in actual environment.

2. DESIGN OF MICRO GRASPING DEVICE

The design of micro grasping device is concerned with many aspects, especially the assembly of micro devices, manufacturing and integration of the other electronic components. Further, the design must be of differential type actuators (agnostic and antagonistic), which should be controlled opening and closing of the gripper jaws. Monolithic compliant mechanism is the better solution for the micro manipulating devices [7]. To attain high precision in positioning, repeatability and stability, one of the jaws of the micro grasping device is designed to as fixed part.

To obtain the compliant mechanism, topological optimization technique has been used. The existing MATLAB program [8] is modified to develop the proposed design domain to attain the new compliant design. SIMP algorithm is used to optimize the design domain. In this program, the objective function is to minimize the material distribution over the design domain subjected to the loading and boundary conditions. The initial design domain is intuitively determined as input to the program with loading and boundary conditions, that is, input force, output spring stiffness, volume fraction and penalization power and the density of the material are taken as ‘1’ for material exists and ‘0’ as void.

The output of the MATLAB program is shown in Fig.1, where the dark grey regions are the presence of material and the white regions are the voids. The design should be subjected to post optimization process. The output topology of the design is necessary to be modified and improved in design to obtain a final design. MATLAB output topology is imported in to AutoCAD, a solid modeling package to model and to do post optimization process. In the post optimization process, the developed design is introduced with the flexure hinges at the location where the single node contact created as shown in Fig.2. Few other changes are also made intuitively at the load applying handle. Fixed portions of the device are also introduced in the design as shown in Fig.3.

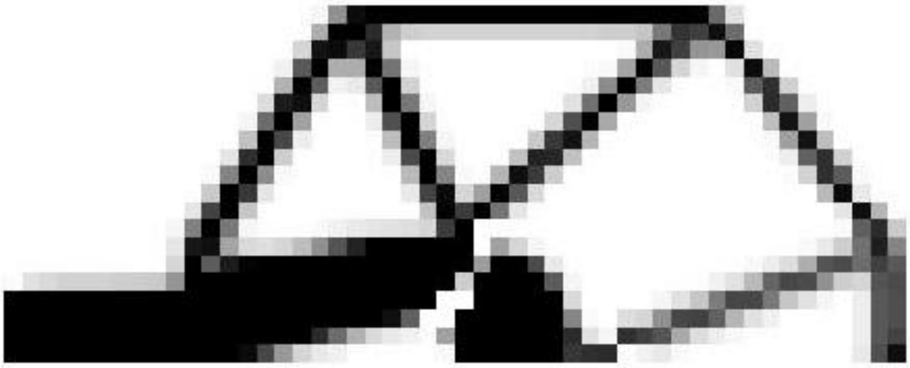

Fig. 1. Topologically optimized design from MATLAB program output.

(a) (b)

Fig.2. (a) Single node contact area (b) Post optimization processed model.

3. STRUCTURAL ANALYSIS

Structural analysis of the micro grasping device was performed in ANSYS, Finite Element Analysis software to obtain the geometrical advantage and other important parameter that influence the design.

In the first step of the post processing, AutoCAD 2D model is imported in to ANSYS software for developing Finite Element Meshing of the model. Aluminium-2024 is considered for the analysis because it has a better machinability character and is easy to attain good surface finish. Material property values of the aluminium 2024 are, Young’s modulus = 73 GPa and Poisson’s Ratio = 0.33. Plane 8-node-183 element has been used to prepare the mesh of the model and is illustrated in Fig.4. This higher order element is appropriate for the micro sized irregular geometrical application. The flexure hinge portion in the model requires more attention and accurate solution; therefore, it is refined to smaller elements.

Input displacement is applied to the handle to actuate the grasping device and the fixed jaw portions are constrained with all degrees of freedom (dof) as shown in Fig.4. The initial displacement value of 0.01 mm is applied in positive x-direction to predict the movement of the output jaw of the grasping device.

For the above mentioned conditions, the model was solved and results were observed in ANSYS.

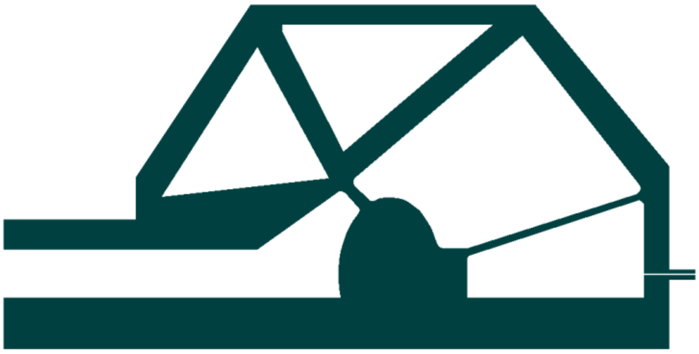

Fig.3. 2D Geometric model for the MATLAB output after post optimization process.

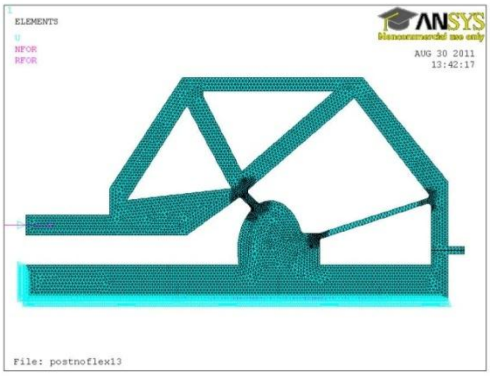

Fig.4. FE model of micro grasping device with Loading and Boundary Conditions

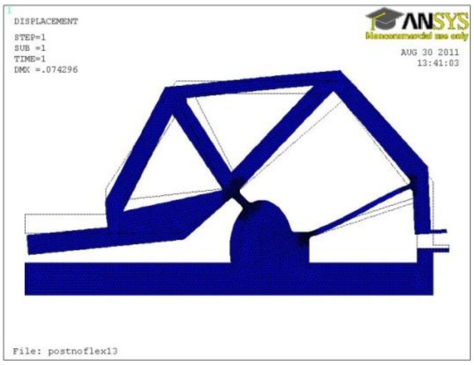

Fig.5. Deformation results of the micro grasping device.

4. RESULTS AND DISCUSSION

Fig. 5 shows the deformation summary of the results of the micro grasping device for the applied input displacement. The input displacement may be obtained by any of the actuation technique ranging from mechanical actuation to shape memory alloy systems. Both the deformed and un-deformed edges are shown in the Fig. 5 to clearly understand the level of magnification factor achieved at the output jaw. Fig.6 shows the contour plot of the deformation of the moving jaw in vertical direction. Maximum deformation is occurred at the tip portion of the moving jaw pointed as 'MX' in Fig.6. The maximum output displacement at the jaw is found to be 0.074 mm for the given input displacement of 0.01 mm. This has been proved that a large magnification factor of 7.4 is achieved in this proposed design of the micro grasping device compared to the other designs found in the literatures. Pure rotational displacement is found at the pivot portion in the simulated results.

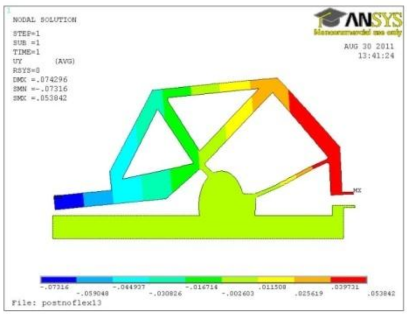

Fig.6. Contour plot of the deformation results (UY direction).

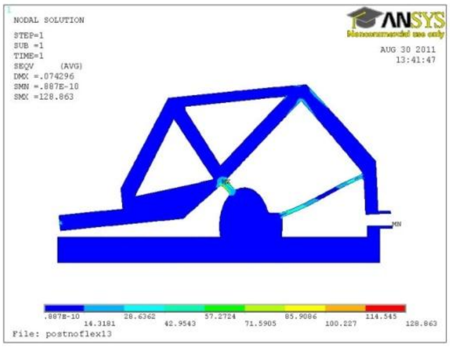

Fig.7. von-mises result obtained from FE analysis

Von-Misses stress developed in the design is observed to be maximum at the location where the flexure hinges are introduced and the stress value is noted to be 128.83 N/mm^2 with minimum stress induced at the jaw tip (Fig. 7). But the developed stress value is found to be within the limit of the design stress of Aluminium 2024.

Geometrical advantage (GA) is the important parameter for any micro grasping device. Most of the researchers have attained GA values between 3 and 6. From this new design the GA is improved to 7.4.

G.A. = (output displacement / input displacement)

G.A. = 0.074 /0 .01 = 7.4

5. CONCLUSION

A new design of micro grasping device for MEMS applications has been proposed with flexure hinge based compliant mechanism. Topological optimization technique has been carried out by developing a MATLAB code and the post optimization processed design was subjected to FE analysis to investigate its deformation and stress distribution. It is found that the greater geometrical advantage of 7.4 has been achieved in this design. From the results, it is concluded that this design will be suitable for MEMS applications where higher geometrical advantage is required.

Appendix A. Modified MATLAB Code

```
% DEFINE LOADS AND SUPPORTS
din = 2*(nely+1)-1;
dout=
2*(nelx)*(nely+1):2*(nelx):2*(nelx+1)*(nely+1);
F(din,1) = 1;
F(dout,2) = -1;
K(din,din) = K(din,din) + 0.1;
K(dout,dout) = K(dout,dout) + 0.1,
fixeddofs=
union([2*(nely+1)*27:2*(nely+1):2*(nely+1)*30],
[2*(nely+1)*27-1:2*(nely+1):2*(nely+1)*30-1]);
alldofs    = [1:2*(nely+1)*(nelx+1)];
freedofs   = setdiff(alldofs,fixeddofs);
Uout = U(dout,1);
```

REFERENCES

[1] Sigmund O (1997): On the design of compliant mechanisms using topology optimization, Mechanics of structures and machines , **25** (4), pp.493-524.

[2] C J Shih and C F Lin (2006): A two-stage topological optimum design for monolithic compliant microgripper integrated with flexure hinges, Journal of Physics: Conference Series, **34**, pp.840–846.

[3] Pretty Khare, G. B. Madhab, C. S. Kumar, and P. K. Mishra (2007): Optimizing Design of Piezoelectric Actuated Compliant Microgripper Mechanism, NaCoMM07, IISc, Bangalore, India, December 12-13.

[4] N. Maheshwari, A. Narayana Reddy, Deepak Kumar Sahu and G.K. Ananthasuresh (2009): “Miniature Compliant Grippers with Force-Sensing,” NaCoMM09, NIT, Durgapur, India, December 17-18.

[5] Mohd Nashrul Mohd Zubir, Bijan Shirinzadeh (2009): Development of a high precision flexure-based Microgripper, Precision Engineering, **33** (4), pp. 362-370.

[6] Bijan Shirinzadeh, Yanling Tian (2009): A new design of piezoelectric driven compliant-based microgripper for micromanipulation, Mechanism and Machine Theory, **44** (12), pp. 2248-2264.

[7] S K Nah, Z W Zhong (2007): A microgripper using piezoelectric actuation for micro-object manipulation,” Sensors and Actuators A: Physical, **133** (1), pp.218-224.

[8] M. Bendsøe and O. Sigmund.(2002), Topology Optimization - Theory, Methods and Applications. Springer Verlag, Berlin Heidelberg New York.

[9] Marius M. Blideran Günter Bertsche, Wolfgang Henschel and Dieter P. Kern (2006): A mechanically actuated silicon microgripper for handling micro- and nanoparticles, Microelectronic Engineering, vol. 83(4-9), , pp. 1382-1385.