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Displacement Analysis of Rectangular and Circular Hinge for Compliant Micro–Gripper

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Abstract: *The growing research field of precision instruments in every walk of life motivated to different and efficient technology. The millimeters have cut down to micrometer or even nanometers. This has led to development of compliant mechanisms. The gripper comprises of very simple structure from design and manufacturing consideration. The selection of the hinges plays a very important role as they replace the conventional torsional springs. The paper deals with the two design methods most widely used for designing the compliant gripper including the FEA and Pseudo Rigid Body Method. In this work rectangular and circular type hinges are considered. From the results obtained we can state that we get more logical and accurate results using the PRBM. Hence the error obtained in result of circular and rectangular hinge is 6% and 16% respectivelywhen compared with FEA results. The dimensions of aforesaid micro-grippers are 50 X 30 mm. The force range of the gripper is from 10N to 50 N.*

***Keywords** –Compliant Mechanism, Hinge,PRBM, FEA.*

I. Introduction

Traditional mechanisms contain rigid links which are connected by movable joints and are able totransforming linear motion into angular, force into torque.

Nomenclature
b= thickness of mechanism
r= radius of flexure
t= neck thickness of flexure

In industry, a new type of mechanism is developed, which strictly adhere to the Linear or Angular motion, force transfer, in a required direction without any friction [1]. They are jointless, thus they don't have energy loss due to wear and friction as compared to the traditional. The working of compliant mechanism is totally based on the elastic deformation. Compliant mechanisms are dust-dirt free of all and application oriented, as they work on the principle of strain energy stored in flexible elements [2].The mechanisms are used widely for various applications depending upon the requirement of precision in a focused field. The widestapplications of precision instruments in a biomedical research thus there precision range is down to nanometers from millimeters, the main application is cell handling [3]. For handling such a small level parts grippers have been developed which facilitates the gripping and manipulating of microscopic objects for micro assembly tasks [4].There are several other manipulation techniques like Bernoulli, optical, magnetic, electrostatic and ultrasonic, on the contrary the micro grippers working on the principle of strain energy are mostly preferred due to their flexibility and accuracy in handling micro objects with complex shape objects at less cost.[5] Different class of micro grippers have been developed with different ways over the period of time, consisting of methods like PRBM technique and distributed compliance technique[6]. But mostly used is the PRBM. M.R.Arvind, et.al [7] developed a micro-gripper by considering the 2D- flexure hinge parameters of two types of hinges and the effects of critical parameters and location of hinge on the output displacement andstiffness of gripper have been proposed. Nah &Zhong [8] designed, fabricated and tested a micro-gripper using Piezoelectric actuator for handling gear and wire of various displacements, with 170 microns stoke and geometrical advantageof 3 mm. Zubir&Shirimzadeh [9] developed a precision based parallel motion micro-gripper by cantilever beam theory and using PRBM method, Gripper attained maximum jaw displacement of 100 micron and amplification factor of 2.85 and compared results using FEM, Gripper with optimized rigid links has been developed. Petkovic and et al. [10] have developed micro gripper for gripping of irregular shape and sensitive objects, usingneuro-fuzzy approach with distributed compliance. It is under actuated adaptive gripper and optimized each parameter of geometry. It have been estimated the gripper behavior for grasping and lifting up the objects. Kang and Wen[11] developed a gripper for handling micro assembly objects purpose and used PRBM approach, circular notch type of hinges are used. Nikoobin and Naiki [12] critically analyses effective parameters for gripper design and performance on basis of sixteen different models of micro grippers. They have been proposed parameters such as material specifications, displacement amplification, gripping range and stroke motion of jaw etc. and different shapes of tips were also reviewed. Krishnan and Saggere[13] developed micro gripper for manipulation of irregular shape small sized objects for any direction orientation and proposed obtained a maximum geometrical advantage of 11.56 by rotational flexures concept. It canable to handle the objects within the range of 100 microns. Flexural Hinges are the flexible members having bending motion for producing limited rotation between two rigid links. Design of flexural hinges depend on precision of rotation, capacity of rotation, stress levels, energy consumption and energy storage which is very important [14]. Yong, Lu and Handley [15] reviewed all the types of flexural hinge theories and found out the percentage error for different hinge design equation on the basis of t/r ratio. Chain and Howell[16] studied torsional compliance approach and proposed two equations which are independent of t and b and these equations proved to be useful for variable cross-sections..

II. METHODOLOGY AND GEOMETRIC MODELLING

2.1 Hinge Design:

For gripper design dimensional constraints considered are (50 x 30 mm.).In PRBM hinges are replaced by torsional springs for mathematical modeling, the type of hinge selection is depending on the application for which the mechanism is designed. The flexure hinges can be selected based on their performance during operation according to the following factors:

- Precision of rotation
- Stress levels under fatigue conditions
- Sensitivity to parasitic loading,
- Capacity of producing the desired limited rotation.

The gripper design proposed in this work lie under the 2-D application. For this type of application hinges used is circular and rectangular type. These hinges are selected because of their advantages in limited rotation application. Forces and moments acted on circular hinge with dimensional detailing are shown in Fig. 1. Spring rate of circular type of hinge is given by equation (1) and spring rate for rectangular type of hinge is given byequation (2) [7].

$$k_\theta = \frac{2 * E * b * t^{2.5}}{9 * \pi * r^{0.5}} \quad (1)$$

$$k_\theta = \frac{E*I}{2a_x} \quad (2)$$

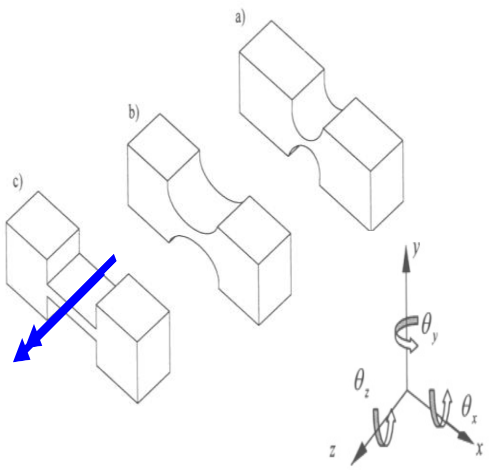

Fig.1. Circular and rectangular hinge used in PRBM   Fig.2 Gripper with input Force F

2.2 PRBM Analysis

The circular and rectangular hinge modelsareanalyzed by using following equation (Eqn.3) to obtain displacement at the tip of the gripping arms [13].

$$X=\frac{1}{N}FL^2\frac{1}{k_\theta} \quad (3)$$

Input Force (F), No.of hinges (N) = 8, Elasticity (E)= 200 GPa, Poisson's ratio= 0.3, Mass density= 7,850 kg/m^3.

The displacement results for both types of hinges are found by PRBM and compare both hinges for different input forces at range of 5 N to 50 N.

III. FINITE ELEMENT ANALYSIS (FEA)

The models are saved in the format of .igs in CATIA V5.These models for different hinge type is shown in Fig.3 and Fig.4. Those models are imported back into ANSYS WORKBENCH for the purpose of meshing and analysis. Fine type of meshing is selected for accurate results. The boundary conditions are put on modelled gripper as per requirement and after meshing, displacement parametric analysis for different input force is carried out in FEA for structural steel material. FEA displacement analysis results for rectangular and circular are shown in Fig 5 and 6 respectively.

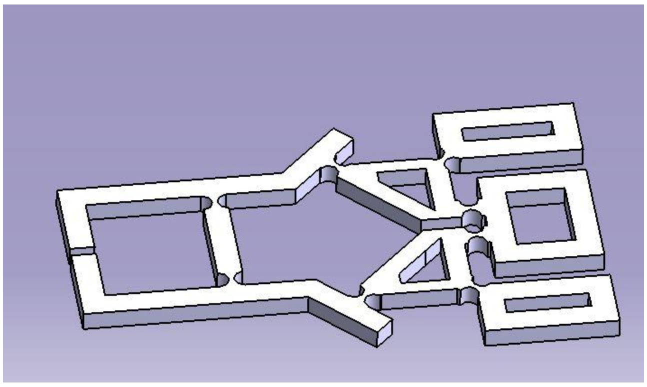

Fig.3.Circular Hinge Gripper Model.

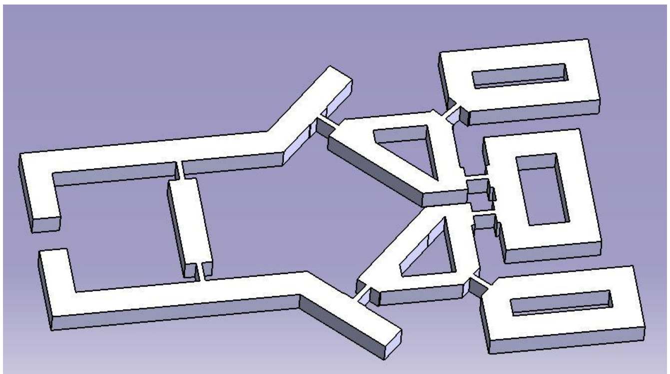

Fig.4.Rectangular Hinge Gripper Model.

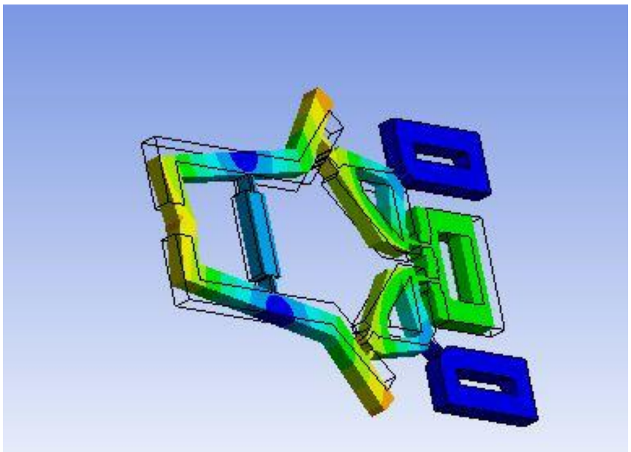

Fig 5. Displacement result Rectangular Hinge

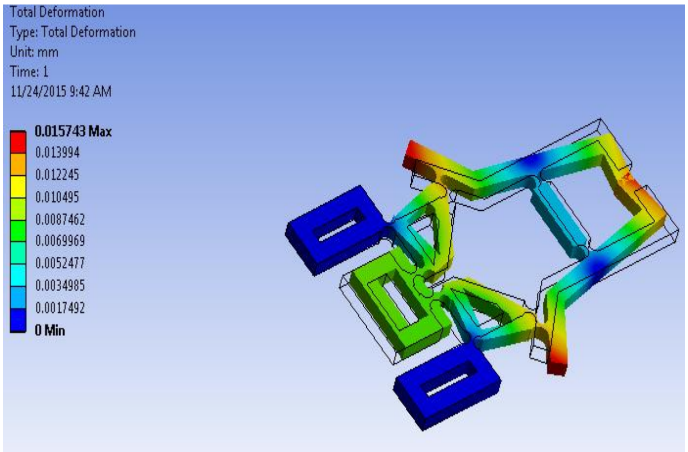

Fig6. Displacement result Cicular Hinge

IV. COMPARISON OF PRBM & FEA RESULTS

The displacement given by PRBM at various input forces are compared with the results after FEA for both type of hinges shown in Table 1. And there graphical comparison for each hinge is shown in Fig 7 & 8.

Table 1 – Comparison of displacement results of Circular and Rectangular hinge.

	Rectangular Hinge			Circular Hinge		
F (N)	**PRBM**	**FEA**	**% Error**	**PRBM**	**FEA**	**% Error**
5	0.017171	0.02056	16.50	0.014582	0.016532	6.338261
10	0.034343	0.041131	16.50	0.029609526	0.031486	6.338261
15	0.051514	0.061697	16.50	0.044414289	0.047229	6.338261
20	0.068686	0.082263	16.50	0.059219052	0.062973	6.338256
25	0.085857	0.102828	16.50	0.074023815	0.078716	6.338261
30	0.103029	0.123394	16.50	0.088828578	0.094459	6.338258
35	0.1202	0.143960	16.50	0.103633341	0.110202	6.338261
40	0.137372	0.164526	16.50	0.118438104	0.125945	6.338256
45	0.154543	0.185092	16.50	0.133242867	0.141688	6.338256
50	0.171715	0.205657	16.50	0.14804763	0.157431	6.338259

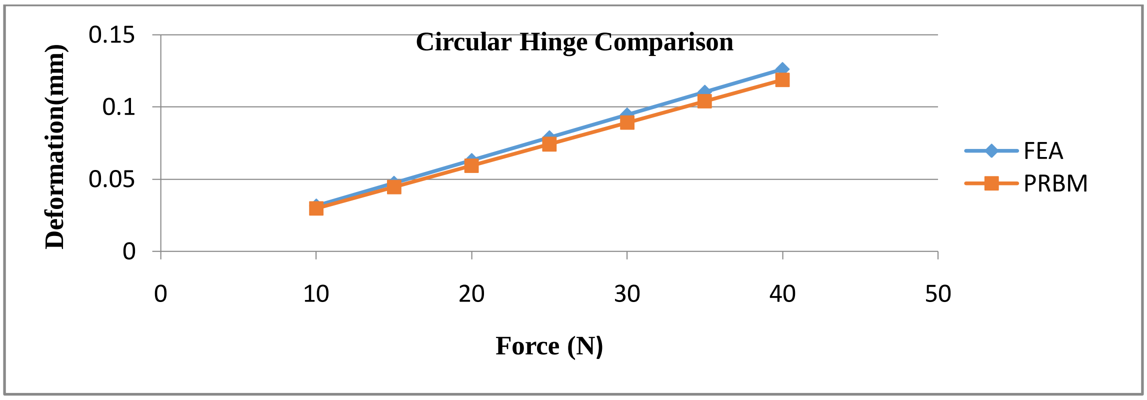

Fig.7 Circular hinge comparison for PRBM and FEA

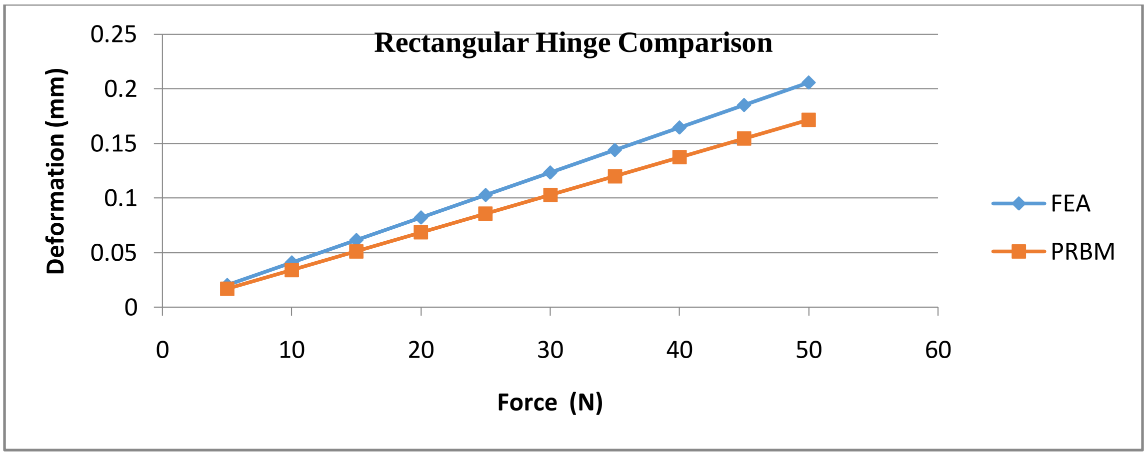

Fig.8 Rectangular hinge comparison for PRBM and FEA

V. CONCLUSION

The gripper developed using PRBM for displacement model and validated using FEA. The shape of the gripper comprises of simple structural shapes which are combined to form final geometry necessary to obtain the desired deformation. The PRBM technique is easy to apply and understand in design and analysis of compliant mechanisms for specific applications. Hinge design plays a vital role in designing mechanism using PRBM which completely affects the output performance of the compliant gripper. The results showing 6% and 16% offset from PRBM for circular and rectangular hinges respectively because of accuracy factor and meshing errors (duplicate elements, element size and type) in FEA software. It can be concluded that rectangular hinges give more displacement output with low level of stress formation at hinges.

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