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DESIGN ANALYSIS AND VALIDATION HIGH PRECISION FLEXURE MECHANISM

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ABSTRACT

The present article discusses about the modeling of S shaped flexure mechanism built with double parallelogram manipulator (DFM) as building blocks. It generates motion between fixed support and motion head. It is built is single monolithic and compact in design as compared to rigid linkage. The finite element analysis is carried out in ANSYS15. The experimental test is carried out on the flexure mechanism integrated with dSPACE DS1104 R & D controller. DFM consists of actuator, optical encoder and DAQ system. The values obtained are in close match with FEA results. The voice coil motor is actuated by Linear Current Amplifier (LCAM) which get inputs as amplitude and frequency. The moment of the mechanism is detected by optical encoder and gives analog voltage to the output moment of the shaft. In applications such as nanometric positioning, the high-quality motion quality of flexures so strongly minimizes any limitations that most existing nano-positioners are basically based on flexures. An additional advantage of using flexures is that the trouble of assembly can be minimized by creating the mechanism monolithic. This makes flexures essential for micro-fabrication, where assembly is mostly tough, or even impossible. Thus, despite small range of motion and a important performance compromise between the DOF and DOC, flexures remain important machine elements.

Keywords: DAQ, Optical Encoder, LCAM, dSPACE DS1104, Flexure Mechanism

1. INTRODUCTION

Research and development in nano & micro scale applications with high precision. Precise positioning used in flexure mechanisms, MEMS applications, lithography systems etc. flexure mechanisms provide desire motions for the flexural hinges with smooth operations and frictionless without lubrication with free and clean operation [1-3]. The initial investigations of flexure joints influence geometric parameters and performance characteristics like stiffness, motion stage, accuracy stresses [4-6] are calculated and compared with different sections using FEA Tool Ansys Work Bench. Efficient flexure mechanism for applications is needed to select the geometric parameters to optimize it. Parametric model is built using Ansys tool to simulate the characteristic of the joints. For nano measuring instruments the resolution positioning and millimeter travel range are required [7-8]. In this paper flexure mechanism is developed to obtain amplification up to 1:5 scales. The cross section of the mechanism lever is modified to S shaped structure and monolithic (one piece). The figure 1 is shows S Shaped Flexure Mechanism.

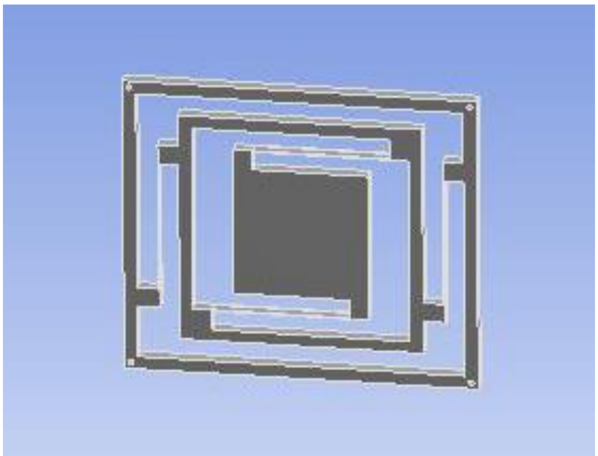

Figure 1: S Shaped Flexure Mechanism

FEA analysis is carried out to evaluate the travel range of mechanism. The paper is organized as literature survey in section 2, FEA analysis of flexure in section 3, Experimental setup section 4, conclusion in section 5.

2. LITERATURE REVIEW

Evaluated and verified stiffness equation flexure hinge for cartwheel. The cartwheel was evaluated for various parameters stiffness linear range, compared with hinge of right circular to conform the similarity to cartwheel flexure hinge for range of large displacement joint flexure [9-10]. New design was invented to translation and rotation compliant joint. Various models built with parametric to verify the stiffness and range by using Finite Element Analysis. The merits over the exiting flexure range and axis drift increased and stress concentration is reduced [11-14]. Large displacement XY positioning stage over constrained mechanism. The theory of screw system was used. The weight support mechanism of motion was used as a linear actuator. The single stage range was large displacement of 200x200mm. FEA was done and verified by mathematical modeling. Effectiveness of nonlinear model is done by both FEA and experimental studying on prototype. Proper dynamic model of XY was built [15-18]. A compliant joint was proposed and analyzed using FEA Tool [19]. Extensive parametric analysis in sizing joints of different application. Electromagnetic actuators used to drive XY Mechanism [20-22]. Stages where built with DFM and validated using FEA and forces were generated [23-25]. Proposed a generic parallel kinematic constraint pattern. Topologies generated by constrain behavior of flexure [26-27]. Nonlinear FEA Verified by constraint beam to check accuracy and effectiveness [28-30]. The constrained model involves various boundary conditions, loading conditions and beam shape. 2D beam flexure of closed form parametric load displacement model was built with nonlinearities stiffness and errors are quantified with load, stiffness, elasto kinematic and kinematic effects [31-32].

3. FINITE ELEMENT ANALYSIS OF DOUBLE FLEXURE MECHANISM

Finite Element Analysis is a numerical method. The method of complexity solving the problem such as shape, boundary conditions and loads. The results are obtained by approximate. Materials used for the analysis having properties as 2e11Pa young's modulus, possion ratio 0.3 and density of material 7860kg per cubic meter.

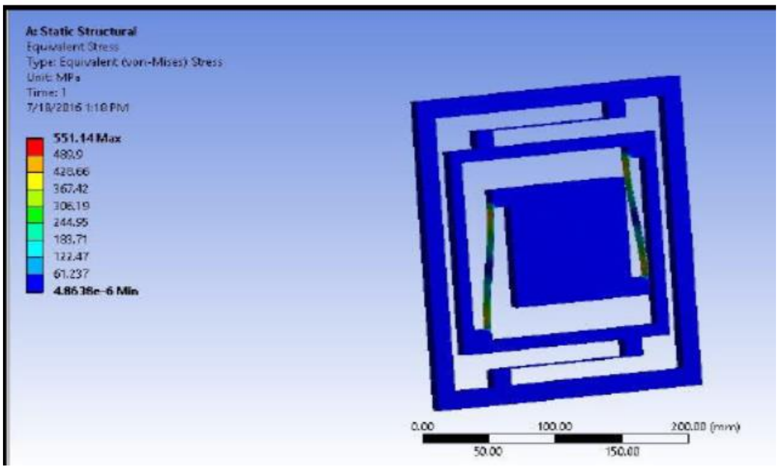

Figure 2: Maximum stress developed in X-direction.

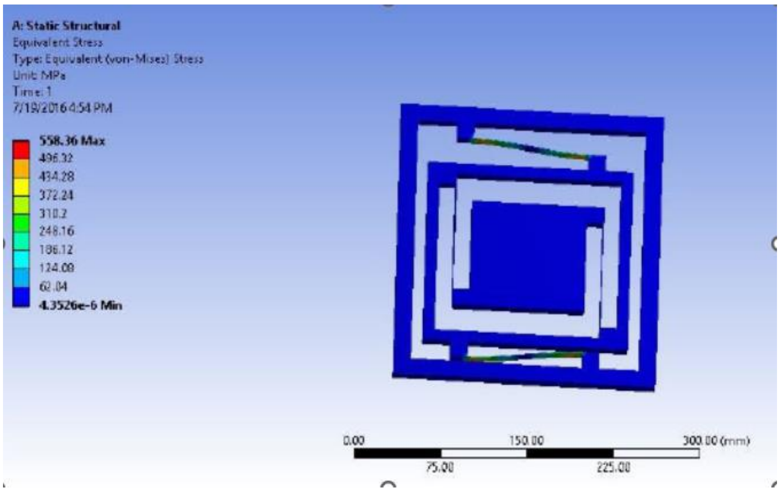

Figure 3: Maximum stress developed in Y-direction.

The maximum (von-mises) stress created at the Flexure is 551.14 MPa in X direction and 558.36 MPa in Y direction. The material used for Flexure is Mild Steel. The Tensile Yield Strength of Mild Steel is 590MPa. Thus, the maximum (von-mises) stress generated at the Flexure is within the permissible limit. Therefore, the design is safe.

Table 1. Comparison of Stresses.

Sl No	Force Applied N	Maximum Stress (Mpa)	
		X Direction	Y Direction
01	01	36.574	37.753
02	05	124.86	133.68
03	10	236.98	244.97
04	15	349.68	356.89
05	20	461.38	468.82
06	25	551.14	558.36

The model analysis is carried and the results obtained are shown in figure 2 & 3.

The frequencies for the Mechanism are as below table 2.

Table 2. Mode shape and Frequency Values.

Mode Shape	Frequency Hz
01	6.664
02	8.6292
03	42.107
04	51.290

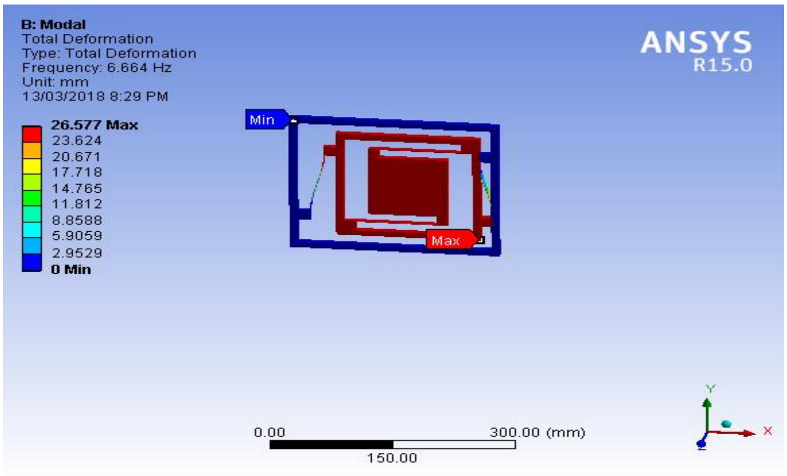

Figure 4: Mode Shape 1

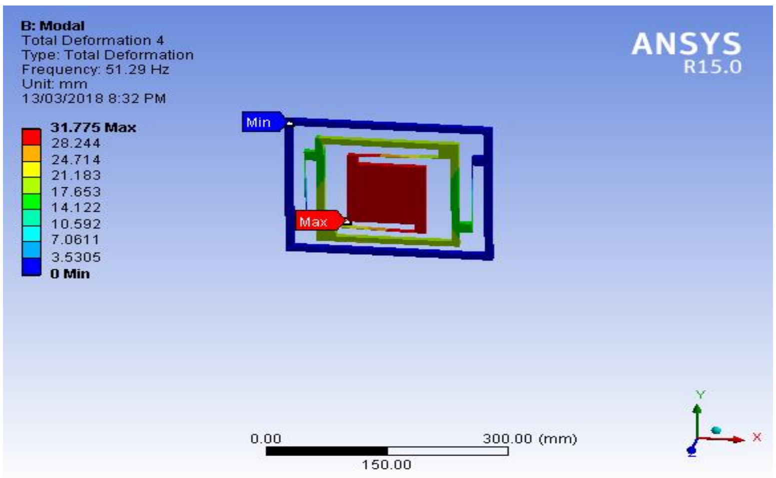

Figure 5: Mode Shape 2

The modal analysis evaluates the vibration characteristics of the mechanisms. The transient, dynamic analysis and harmonic analysis solve the resonant frequency and mode shape. The FEA Plot is obtained as shown in figure 4 and 5.

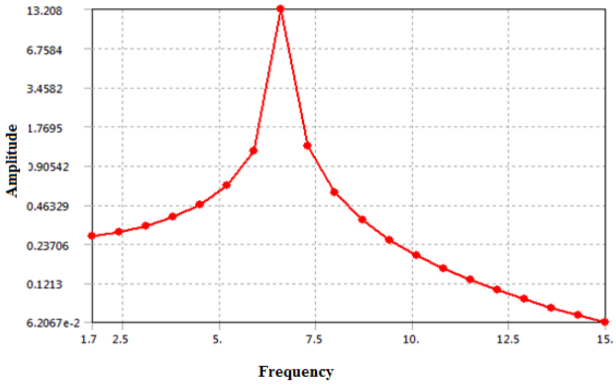

Figure 6: Harmonic response of the model

The obtained harmonic response of the S Shaped Flexure mechanism is 13.208 frequencies.

4. EXPERIMENTAL SETUP

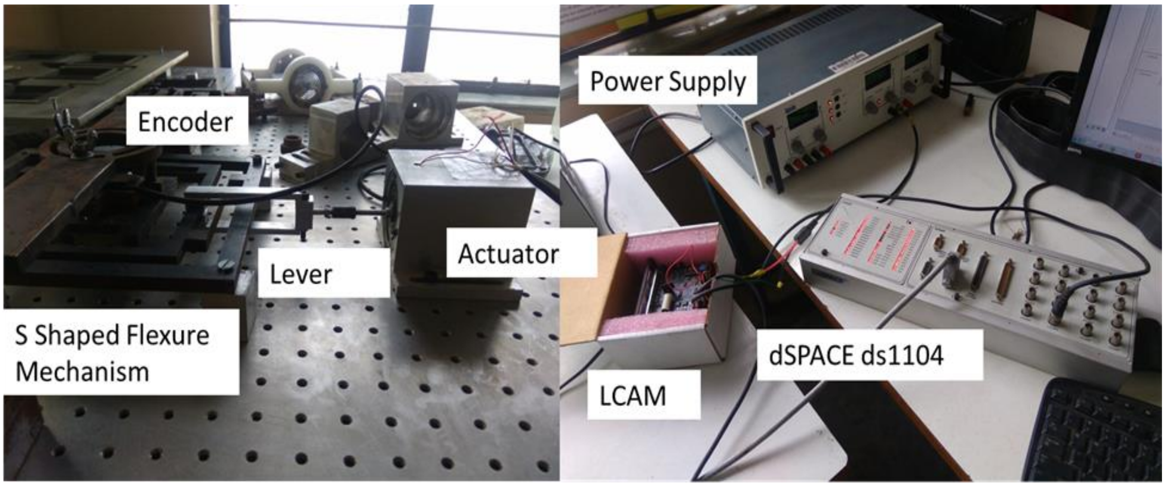

Figure 7: Experimental Setup of S Shaped Flexure Mechanism

The experimental setup consists of a Lever which is attached to the S Shaped flexural mechanism in X-Y direction via a VCM to actuator. The whole mechanism is fitted on vibration free base (i.e. Optical Bread Board) by seating it on 4 metal mounting blocks, secured with the help of M6 bolts. The optical encoder gauge measures the output displacement with the help of the dSPACE ds1104 microcontroller attached to the motion stage. The mechanism is actuated by the Voice coil motor which is clamped by the lever. The set-up needs to be adjusted for X and Y directions, respectively.

The figure 8 shows the Step response curve of the system model. The amplitude of the system model decreases with increase in time.

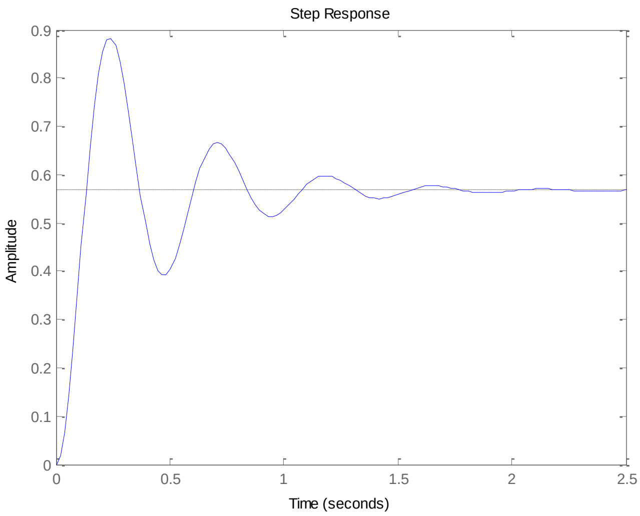

Figure 8: Time vs Amplitude

Frequency response of DFM with amplitude 1.7640mm, a frequency response curve for the system is generated to analyze the natural frequency of the system and the phase change. The frequency response curve of the system obtained to do the analysis of the natural frequency of the flexure system and the behaviour of the phase change for the amplitude of 1.5mm. frequency response curve is shown in figure 9.

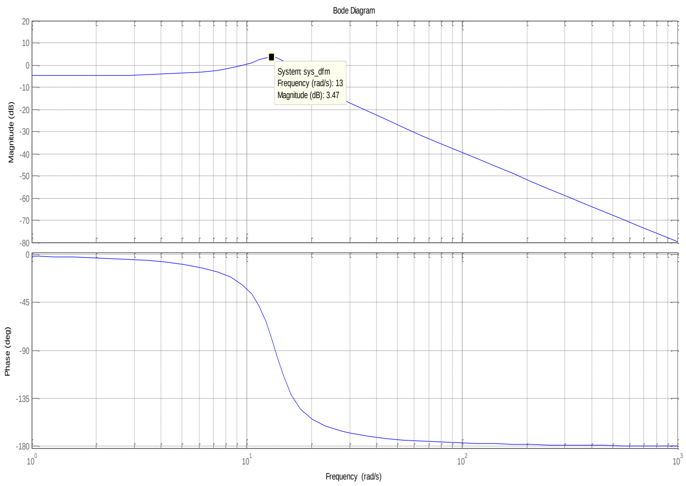

Figure 9: Frequency response of the system

The results obtained with FEA harmonic analysis and experimental values are close agreement with each other.

5. CONCLUSION

In this paper XY flexure mechanism designed with S Shaped structure useful in precision applications in Scanning, microscopy and many more. It has zero backlash and zero friction which offers control on precision position. It is built with the control model using dSPACE DS1104 Control desk. The dynamic analysis using frequency response quality of mechanism with various frequencies. The frequency response is used for experimental modeling. The experimental values are validated with FEA values with close match.

6. REFERENCES

[1] A Kalaiyarasan, K Sankar, S Sundaram Finite element analysis and modeling of fractured femur bone, Materials Today: Proceedings, 2019, Volume 22, Part 3, 2020, Pages 649-653

[2] Khilare, Umesh A., and S. B. Sollapur. "Investigation of Residual Stresses and Its Effect on Mechanical Behaviour of AISI310."

[3] Shinde, Tarang, et al. "Fatigue analysis of alloy wheel using cornering fatigue test and its weight optimization." Materials Today: Proceedings 62 (2022): 1470-1474.

[4] Shrishail Sollapur, Saravanan, D., et al. "Tribological properties of filler and green filler reinforced polymer composites." Materials Today: Proceedings 50 (2022): 2065-2072. https://doi.org/10.1016/j.matpr.2021.09.414

[5] Raut, P.P., Rao, A.S., Sollapur, S. et al. Investigation on the development and building of a voice coil actuator-driven XY micro-motion stage with dual-range capabilities. Int J Interact Des Manuf (2023). https://doi.org/10.1007/s12008-023-01665-2

[6] Shrishail, B. Sollapur, and P. Deshmukh Suhas. "XY scanning mechanism: a dynamic approach." International Journal of Mechanical Engineering and Robotics Research 3.4 (2014): 140.

[7] Swapnil S. Shinde, Shrishail B Sollapur, "Effect of Residual Stress on the Mechanical Behavior of AISI 304, For TIG Welding", International Journal of Scientific & Engineering Research(IJSER), Volume 8, Issue 10, October-2017.

[8] Toradmal, Kuldeep P., Pratik M. Waghmare, and Shrishail B. Sollapur. "Three-point bending analysis of honeycomb sandwich panels: experimental approach." International Journal of Engineering and Techniques 3.5 (2017).

[9] S B Sollapur et. al "Mechanical Properties of Bamboo Fiber Reinforced Plastics", IJSART - Volume 3 Issue 9 – SEPTEMBER 2017 ISSN [ONLINE]: 2395-1052, Page | 365-368

[10] Khilare, Umesh A., and S. B. Sollapur. "Investigation of Residual Stresses and Its Effect on Mechanical Behaviour of AISI310." Journal for Research | Volume 02 | Issue 05 | July 2016 ISSN: 2395-7549, PP 42-46.

[11] Waghmare, Pratik M., Pankaj G. Bedmutha, and Shrishail B. Sollapur. "Investigation of effect of hybridization and layering patterns on mechanical properties of banana and kenaf fibers reinforced epoxy biocomposite." Materials Today: Proceedings 46 (2021): 3220-3224.

[12] S B Sollapur et. al “Mechanical Properties of Bamboo Fiber Reinforced Plastics”, IJSART - Volume 3 Issue 9 – SEPTEMBER 2017 ISSN [ONLINE]: 2395-1052, Page | 365-368

[13] Gireesh, Belawagi, B. Sollapur Shrishail, and V. N. Satwik. "Finite element & experimental investigation of composite torsion shaft." Int. J. Engg. Research and Applications 3.2 (2013): 1510-1517.

[14] Deore, Om Bipin, Shrishail Sollapur. "Design and Analysis of Complaint Mechanism using FEA." development 7.10 (2020).

[15] Baviskar D.D., Rao A.S., Sollapur S. et al. Development and testing of XY stage compliant mechanism. Int J Interact Des Manuf (2023). https://doi.org/10.1007/s12008-023-01612-1

[16] Shrishail Sollapur, Shraddha Gunjawate, “Structural Analysis and Topology Optimization of Leaf Spring Bracket”, International Journal of Engineering Research & Technology (IJERT) Vol. 9 Issue 07, July-2020. pp. 1448-1494

[17] Sollapur, Shrishail, M. S. Patil, and S. P. Deshmukh. "Position Estimator Algorithm Implementation on Precision Applications." Materials Today: Proceedings 24 (2020): 333-342.

[18] S B Sollapur et. al “Experimental Investigation of High Precision XY Mechanism”, International Journal of Mechanical Engineering and Technology,9(5),2018,pp.43–50.

[19] Sollapur, Shrishail B., M. S. Patil, and S. P. Deshmukh. "Design and development aspects of flexure mechanism for high precision application." AIP Conference Proceedings. Vol. 1943. No. 1. AIP Publishing, 2018

[20] Umesh K, “Identifying Design Alternative For Piping System Upon Assessment Of Composite Material For Suitability To The Engineering Application”, In International Journal of Advanced Engineering Research and Studies EISSN2249– 8974 III/IV/July-Sept.,2014.

[21] S B Sollapur, “Evaluation of Stiffness and Parametric Modeling of XY Flexure Mechanism for Precision Applications”, Journal of Modeling and Simulation of Materials, vol. 1, no. 1, pp. 8-15, May 2018. doi: 10.21467/jmsm.1.1.8-15

[22] Shrishail Sollapur, M S Patil, S P Deshmukh, “Advancement and Experimental Investigation of Voice Coil Actuator utilizing Flexural Bearing”, Journal of Mechatronics and Automation, STM Journals, Vol 5, Issue 2, 2018. pp. 40-45

[23] Shrishail Sollapur, Pratik Waghmare, “Design and Experimental Investigation of XY Compliant Mechanism for Precision Applications”, ECS Transactions, 2022/4/24, Volume 107 Issue 1 Pages 4967

[24] P M Waghmare et al, "A Review Paper on Flexure", International Journal for Science and Advance Research In Technology, Vol 3, Issue 10, 2017.

[25] Pratik Waghmare, “Development and Performance Investigation of Solar Concrete Collector at Different Climatic Conditions”, Indian Journal of Engineering and Materials Sciences, https://doi.org/10.56042/ijems.v30i2.1384

[26] Waghmare, Pratik M., Shrishail B. Sollapur, and Shweta M. Wange. "Concrete Solar Collector." Advances in Smart Grid and Renewable Energy: Proceedings of ETAEERE-2016. Springer Singapore, 2018.

[27] Sollapur, S.B., Sharath, P.C., Waghmare, P. (2024). Applications of Additive Manufacturing in Biomedical and Sports Industry. In: Rajendrachari, S. (eds) Practical Implementations of Additive Manufacturing Technologies. Materials Horizons: From Nature to Nanomaterials. Springer, Singapore. https://doi.org/10.1007/978-981-99-5949-5_13

[28] Chate, Ganesh R., et al. "Ceramic material coatings: emerging future applications." Advanced Ceramic Coatings for Emerging Applications. Elsevier, 2023. 3-17.

[29] Prasanna RautA. S. Rao, Devakant D. Baviskar, “Development & Analysis of XY Stage Mechanism”, International Journal of Research Publication and Reviews, Vol 4, no 12, pp 2518-2523 December 2023, Doi- 10.55248/gengpi.4.1223.123502

[30] Vinod, M., Kumar, C.A., Sollapur, S.B. et al. Study on Fabrication and Mechanical Performance of Flax Fibre-Reinforced Aluminium 6082 Laminates. J. Inst. Eng. India Ser. D (2023). https://doi.org/10.1007/s40033-023-00605-4

[31] Prasanna RautA. S. Rao, Devakant D. Baviskar, “Finite Element Analysis of High Flexure XY Mechanism Using Parametric Modeling”, International Journal of Research Publication and Reviews, Vol 4, no 12, pp 2160-2167 December 2023, DOI- 10.55248/gengpi.4.1223.123436

[32] Nandeesh A Halabhavi, Charan Guru Dayal T, Venkanna A, V Vamsi P “DEVELOPMENT OF AUTOMATIC SPEED SENSING OF VEHICLE USING ARDUINO " International Journal for Science and Advance Research in Technology, 9(11).