Design, Development and Numerical Experiments of Compliant Anchor Mechanism for Clamping Purpose - A Topology Optimization Method

S. Premanandand, G. Arunkumar

Abstract: ***In the present scenario, every industry focusses mainly on the reduction of wastes. Because waste or scrap plays a major part in the economic status of an industry. It also involves the wastage of time, man power, machine power, raw material, electricity etc.Compliant Anchor mechanism is a flexible mechanism that transfer an input force and displacement at one part to an output force and displacement at another part through elastic body deformation. These may be monolithic (single-piece) or joint less structures.This paper elucidates a Compliant mechanism-based part i.e. Compliant Anchor is designed and numerically analyzed for its mobility, strength and durability with various material characteristics. This Compliant Anchorstructure is designed and developed as such Rigid bodiesapplication. Compliant Anchor is précised and exhibits Larger displacement at its wings with smaller strain.In this work the Compliant Anchor is suitably designed based on rectangular slot hole domain in a work piece to clamp the work piece rigidly(Cases-application)in its surface, For that purpose various material characteristics chosen for design and development, The deformation study of the compliant anchor with various material characteristics analyzed through numerical analysis and The final topology optimized design is taken for development in 3D printing technology, This design can be used for various clamping applications suitably based on deformation level and application of external force.***

Keywords: Compliant mechanism, Modern Kinematics, Topology Analysis, Finite element analysis,3DPrinting, Flexure Materials, Automotive devices, Flexural Anchor

I. INTRODUCTION

Compliant devices are flexible in nature to transform or transmitmotion,Compliant Mechanism design may be elastic pairs or Elastic Segments withsinglecontinuum that produce a desired force and displacement (1). It is an elastic continuum that is used to enhance force and motion mechanically. Unlike rigid body mechanism, for very accurate and précised motions the compliant mechanism gains (1).Nature uses bothstiffness structures and flexible structures in living organisms where needed (stiffness structure - tree trunks, bones, teeth and claws), But it more often relies on flexibility.

Tongue, hair, bird wings, tree branches, leaf stems, fish, and single-celled organisms are only a few examples of creations that use compliance to their advantage (1).

The contrast between nature and human design is easily identifiable when humans try to replace one of nature's products. For example, a human heart valve is a compliant one-way valve that is capable of sustaining billions of cycles without failure. However, most current artificial heart valves use a number of assembled stiff parts with pin joints to obtain motion. They also have a comparatively shorter life, because difficulty in blood flow and often damage blood cells.

The proposed design method and analysis addresses flexibility and stiffness issues of the compliant mechanism simultaneously. It aims to attain an optimal balance between these two conflicting attributes. Such techniques are successful in indirectly controlling the local stress levels by constraining the input displacement.

The General Compliant mechanism design involves mainly of the following three measurables, Topology (The Materials connectivity), Size(The area of cross section of each segment) and Geometry (Orientation and position of segments)

In General Topology Optimization Problems for Compliant Mechanisms using a density Interpolation scheme (Rational approximation of material properties (RAMP) method and Globally convergent method of moving asymptotes are used by various researchers (2)

In Compliant Mechanisms designs the Continuum synthesis approach is used here for design of Distributed Compliant mechanism which is purely based on Topology Optimization for structures, In this method the errors are minimized to achieve Geometrical and Mechanical advantage (3)

ThePaper narrates the topology optimization of compliant anchor for clamping mechanism and its objective is to design a monolithic compliant mechanism made by multiple materials characteristics. The level set method for designing monolithic compliant mechanism made of multiple materials is an optimization of continuum heterogeneous structures.

3.0 Problem Formulation:

The problem is the design of a compliant mechanism Anchor mechanism for clamping components in fixtures in which the input force provided by a Plunger rod with an external force acting on it. This compliant mechanism anchor designed such that the wings in anchor amplifies the

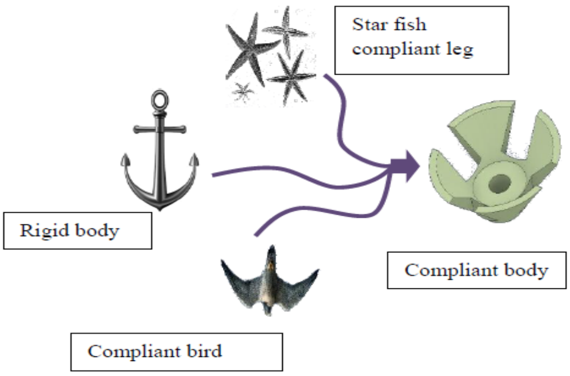
Revised Manuscript Received on 30 July 2019.
***** Correspondence Author
S.Premanandand*, Technical Leader, Brakes India Private Ltd, Polambakkam, 603309, Tamilnadu, India.
Dr.G.Arunkumar, Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, 600119, Tamilnadu, India.

displacement and forced into any component holes and act as a rigid clamping system.

3.0.1 Motivation:

- A combined collaboration with nature by absorbing
- Star fish legs
- The anchor structures
- The flying bird with a shape of anchor, such as the compliant part

3.1 OBJECTIVES:



- To design and Type synthesis of a compliant mechanism-based model with various materials characteristics to find its stability on flexures by Numerical analysis.

3.2 SCOPE OF THE WORK:

To design and Manufacture a single continuum Anchor with wings without Links and Joints to producedeflection on flexural points with less strain input without fatigue failure.

II. DESIGN REVIEW OF VARIOUS COMPLIANT MECHANISMS

Finite element analysis (FEA) is carried out to investigate the performance and validate the theoretical models for further optimum design of the microgripper (12)

A continuum compliant mechanism transmits applied forces from specified input ports to output ports by elastic deformation of its comprising materials, fulfilling required functions analogous to a rigid-body mechanism.

5.0COMPLIANT ANCHOR DESIGN:

Fig 5.1 shows the 3D solid work design and dimensions of Compliant anchor with wings for plunging and clamping a workpiece part with 10.0mm through square slotin its 3.3mm thickness flat surface, Fig 5.2,Fig 5.3,Fig 5.4 shown are 3D views of the Compliant anchor with wings on all directions.

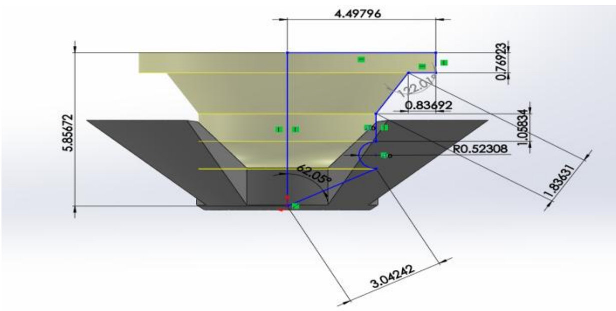


Figure 5.1Compliant AnchorDesign with Dimensions

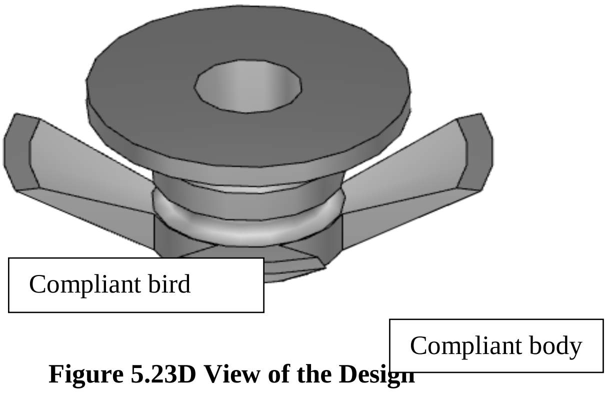


Figure 5.23D View of the Design

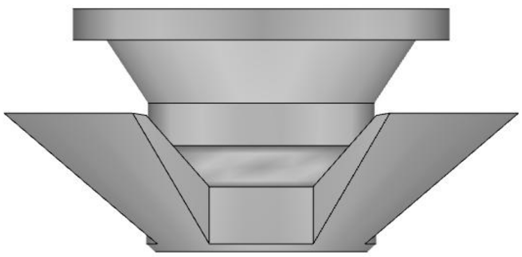


Figure 5.3Front View of the Design

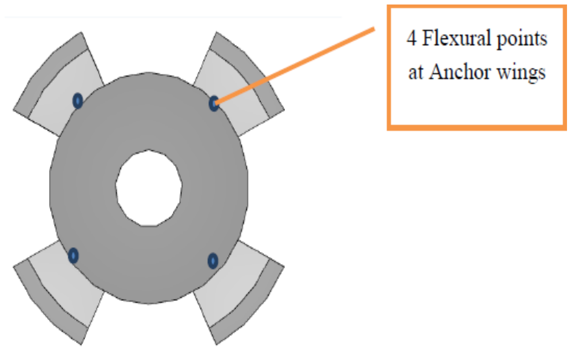


Figure 5.4Top View of the Design

5.0 MATERIAL CHARCTERISTICS STUDY FOR DEVELOPMENT OF COMPLIANT ANCHOR:

The major mechanical properties required for the above application are, High in flexibility, strength, durability, fatigue resistance and Excellent abrasion resistance hence three materials are chosen for its characteristic study and synthesis.

5.1 POLYURETHANE:

Polyurethane (PUR and PU) is a polymer composed of organic units joined by carbamate (urethane) links. The main mechanical properties of PU are, High in load bearing capacity, Flexibility, Fatigue resistance, and wear and tear resistance.

Figure 5.1 Polyurethane Material

5.2 ABS PLASTICS:

ABS or Acrylonitrile butadiene styrene used for various applications specifically for Prototype models. The main mechanical properties of ABS Plastics are, High in Impact resistance, Toughness, Heat resistor, Shock resistance.

Figure 5.2ABS Material

5.3 NYLON:

Nylon is a generic polymerbut comes from a family of synthetic polymers, based on aliphatic or semi-aromatic polyamides. The main mechanical properties are, Excellent abrasion resistance, Strength, More Flexible, Good Specific Strength.

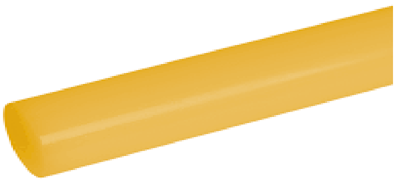


Figure 5.3 Nylon Material

III. COMPLIANT ANCHOR ANALYSIS - POLYURETHANE(PU):

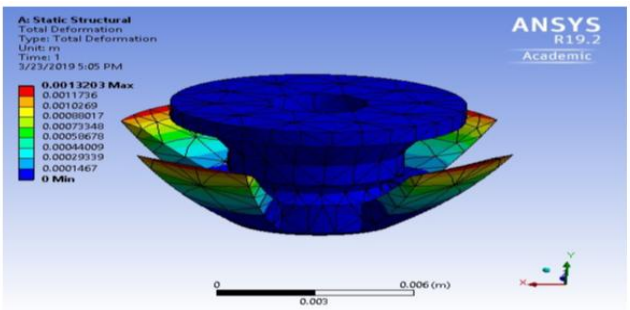


Figure6.1 Compression of PU Compliant Anchor

Here the Part is compressed and stresses on structure is analyzed at totally deformed state, the stresses are found to be higher on Compliant Anchor wings edges in PU Material (Refer Fig 6.1).

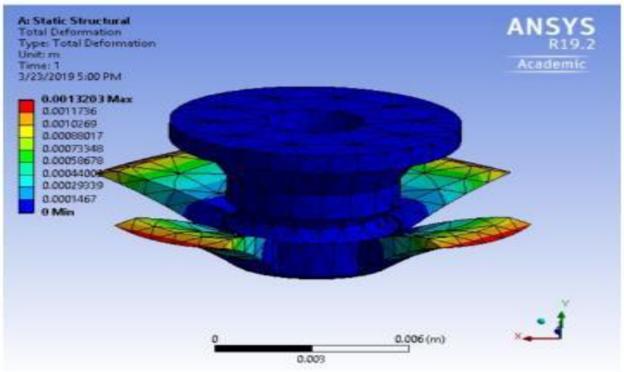


Figure6.2 Expansion of PU Compliant Anchor

Here the Part is expanded and stresses on structure is analyzed at totally deformed state, the stresses are found to be same on Compliant Anchor wings edges in PU Material as like compressed condition(Refer Fig 6.2).

6.3COMPLIANT ANCHOR ANALYSIS –ABS:

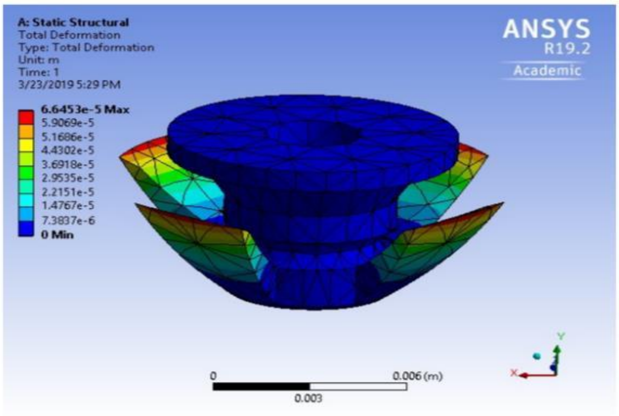


Figure 6.4 Compression of ABS Compliant Anchor

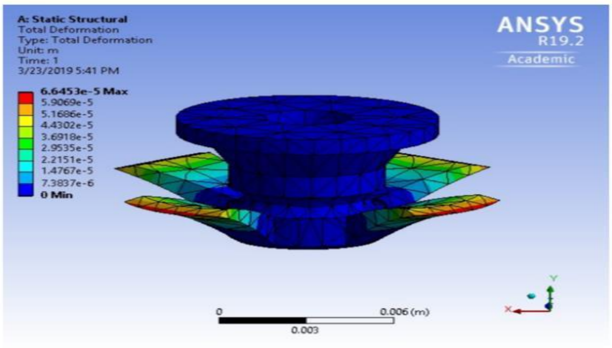


Figure 6.5 Expansion of ABS Compliant Anchor

Here the Part is compressed and expanded and stresses on structure is analyzed at totally deformed state for ABS Plastics, As compared to PU Material the Stress level on the Compliant Anchor wings edges is very low except the sharp edges area in ABS plastics Materialat both the state (Refer Fig 6.4, Fig 6.5).

6.6COMPLIANT ANCHOR ANALYSIS USING ANSYS - NYLON:

Here the Part is compressed and expanded and stresses on structure is analyzed at totally deformed state for Nylon Plastics, As compared to PU Material and ABS plastics the Stress level on the Compliant Anchor wings edges is very low except the sharp edges area in Nylon the deformation of wings is very low compared to other Material characteristics at both the state (Refer Fig 6.7, Fig 6.8).

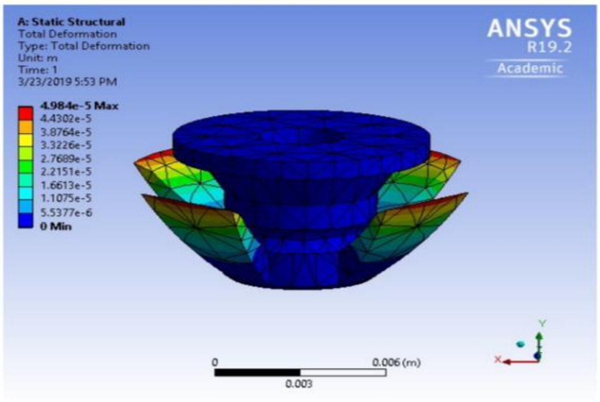


Figure 6.7 Compression of Nylon Complaint Anchor

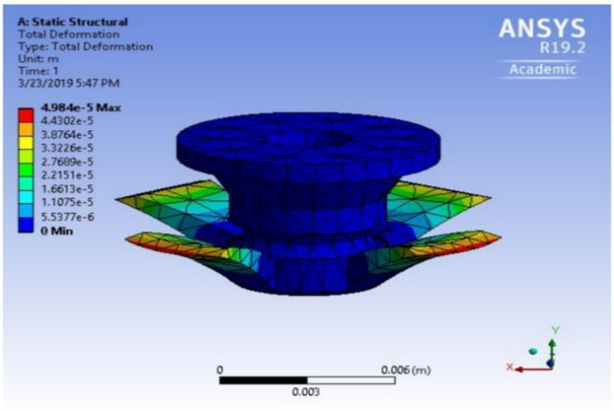


Figure 6.8 Expansion of Nylon Compliant Anchor

IV. RESULT:

The Compliant Anchor design is analyzed for above materials characteristics, themaximum deformations are,

Materials	Maximum Deformation in "m"	Maximum Deformation in "mm"
Polyurethane	0.001320	1.320
ABS Plastics	0.000066	0.066
Nylon	0.000049	0.049

From the above analysis reports, material with less deformations are considered as the best suitable material for the fabrication of Compliant Anchor. Nylon is less flexible material compare to other materials which leads to the fatigue failure of Compliant Anchor during continuous load. Hence, ABS Plastics is the best suitable material for the above required application. Compliant Anchor is fabricated with ABS Plastics using 3D printer.

7.1 FABRICATION:

Fused Deposition Modeling (FDM), or Fused Filament Fabrication (FFF), is an additive manufacturing process that belongs to the material extrusion process, they are a very fame for several applications with ABS material to manufacture low cost prototypes for research works in this 3D printing technology we manufacture material defined tensile strength and stiffness, and its heatdeflection temperature, are real advantages. In this 3D printing process, the Part produced is more accurate in Geometry(Refer Fig 7.2,Fig 7.3,Fig 7.4).

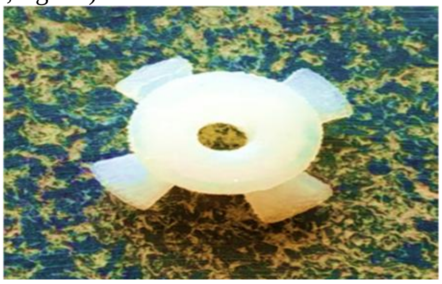


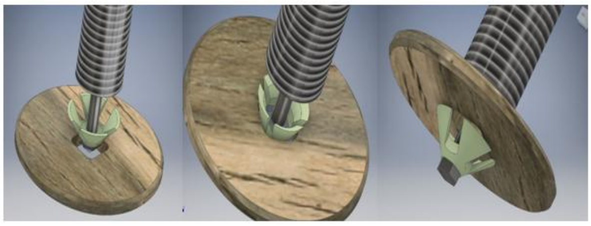
Figure 7.2 Top view of ABS Plastics Compliant Anchor

Figure 7.3 Bottom view of ABS Plastics Compliant Anchor

Figure 7.4 3D view of ABS Plastics Compliant Anchor

8.0APPLICATION OF COMPLIANT ANCHOR – CLAMPING PUPOSES:

Figure 8.0.1Actual Compliant Anchor attached with the Pin Activated Plunger



Case – 1 Case – 2 Case – 3

8.1 Application how it works as shown above in 3 cases

With reference to Figure 8.1 elucidates the three different cases, This Case- 1 complaint anchor part ready to flexure, Case- 2 In this condition the wings of anchor will deflect inner side due to flexural points in itself with respect to application of external force, Case- 3 Based on compliant mass and specimen mass, it will pick up the specimen or it drops down and retainits normal position. This Can be used in mass clamping and inspection stations for detection of missing of holes in work piece.

CONCLUSION

Designing and 3D printingof the Compliant flexural Anchor is done with various material characteristics and studied for its stability and rigidity through FEA,Optimized shape and mechanical advantage of the product is achieved for desirable strength. The weight of a clamping anchor is reduced, Analysis is helpful to Identify the high-stress areasin the compliant anchor with various material characteristics to achieve less deformation without fatigue failure.

This formulation an design of Compliant mechanism meets both the flexural stiffness requirements and withstand the applied Loads in this Compliant Anchor Mechanism.

Finite element analysis feature used to validate the component design through testing part performance under loads. The optimization technology and parametric studies conducted to achieve design parameters within assembly stress areas and compare the various design options. This Model is updated based on these optimized parameters. But in Future works these types of compliant design will be optimized through other Topology Optimization approach (Optimality criteria) to compare on the final optimized Part with reduced weight and fatigue testing to be conducted for the part to know the actual endurance limit of the compliant part.

ACKNOWLEDGEMENT

The author acknowledges the personals who contributed in the field of flexible mechanisms for the enhancement of Automotive, Engineering industry and society

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AUTHORS PROFILE

S.Premanand was born on 10thSeptember 1981 at Chengalpattu, located in Tamil Nadu, India. He has completed his B.E., degree in Mechanical Engineering in the year 2003 at University of Madras, MBA(E-Business) from Annamalai University [Chidambaram] in 2008 and MTech degree in Computer aided Manufacturing in the year 2013 at SRM University, Chennai. An incisive professional with 16 years of experience in Brakes Manufacturing Industry and work experience in Technical Moduleactivities, Production planning, Delivery Operations, Process Enhancement, Quality, Maintenance Management and cost strategy. He is pursingPh.D. in Mechanical Engineering at Sathyabama Institute of science and Technology, Chennai in the year 2018 at present he is working as a Deputy Manager in Brakes India Private Limited, Chennai. He is Certified by ISI as Six Sigma Black Belt for Problem solving works, He is a Certified Internal auditor for Quality Systems (ISO/TS 16949), (ISO 14001) and Safety Systems (OHSAS 18001, He wonVarious awards in various Six Sigma competitions held at ISI Coimbatore, Anna University, ACMA, ABK AOTS.
In is PhD workhis Research activity is in the Field of Mechanical Engineering, Mainly Research scope coversDesign and Topology Optimization of Automotive field parts in which identifying and converting Rigid Body Mechanisms in into compliantmechanisms to Improve overall Vehicle efficiency, Reduction of no of Parts and mainly to achieve Mechanical andGeometric advantage on changing to Compliant devices instead of rigid bodies.He appliedfor membership and registered in Scopus.SERB, His Previous Publication is in International Journal of Mechanical Engineering and Technology (IJMET)Volume 9, Issue 4, April 2018, pp. 748–755, Article ID: IJMET_09_04_083 - Review on design of compliantmechanism for automotiveapplication – a topology optimizationapproach.

Dr. G. Arunkumar was born on 2nd August 1975 at Vellore, located in Tamil Nadu, India. He has Completed his B.E., degree in Mechanical Engineering in the year 1997 at University of Madras, Chennai and M.E degree in Engineering Design in the year 2000 at Bharathiar University, Coimbatore. He secured University second rank in M.E degree course. He has put in seventeen years of Engineering Teaching experience and three years of Industrial Experience. He has completed Ph.D in Mechanical Engineering at Anna University, Chennai in the year 2011. At present he is working as a Professor and Head of Sathyabama Institute of Science and Technology, Chennai.He obtained "Best Faculty Award" during the year 2005 at Kongu Engineering College, Erode. He has been awarded as "Best professor" by Association of Scientists, faculty and Developers (ASDF) in the year 2015. He has been awarded Best Academic Administrator in the year 2017. He secured "Professional Achievement Award 2017" from Society of Engineers and Technicians held at Kulalumpur, Malaysia. He has published papers in refereed International Journal, National Journals and conference proceedings. His research interest includes Design and Numerical Experiments of Compliant Mechanisms, Finite Element Analysis in and Mechanical Design of Heat Exchangers He is a charted Engineer in IE (I), Kolkatta. Member in The Institution of Engineers (I), Member in IET (UK), Life member in Indian Society for Mechanical Engineers and Technicians, Life member in Indian Society for Technical Education. Also, he is a Charted Engineer in IE (I). He was selected as a Lead Engineer by IBS-Cambridge, London, United Kingdom during the year 2007. His biography was published by Marquis Who's Who in the World, USA in the year 2008.