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Design and Development of a Compliant Clutch Fork using Topology Optimization

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Abstract - Compliant mechanisms and its systems are the focus of the active research. It describes a single elastic continuum used to transfer the motion and force mechanically. Their flexibility and stabilities are significant. Topology optimization Method is taken for designing the compliant mechanisms. It is a Material distribution approach for finding the optimum size and shape of the structure. The Author focused mainly on automotive application of Compliant Mechanism.i.e Design and implement of compliant clutch fork using topology optimization. Dimensional data is gathered in order to model the actual clutch fork. Compliant clutch fork designs are developed by reducing the weights compare to actual clutch fork with the help of topology optimization to get optimal compliant design. Experiments are directed to confirm the functionality of compliant clutch fork.

Index Terms: Compliant Mechanism, Topology Optimisation, Clutch Fork, Optimal Design, Reverse Engineering.

I. INTRODUCTION

A compliant mechanism is a flexible structure that deforms elastically to get its mobility from the deflection of flexible members rather than from movable joints only [1][2]. For the compliant mechanism, the input force is transferred to the output port, much like the vice grips mechanism, only now some energy is stored in the form of strain energy in the flexible members [3]. The flexible segment built in such mechanisms replaces the requirement of the various rigid parts, pin joints and add-on-springs [4] and therefore it can save considerable space, the less cost of parts due to usage of less materials, assembly and labour [5]. The benefits of compliance mechanism or devices will lead to reduction of weight, noise, friction, wear and maintenance cost [6]. There are various compliant mechanisms designed with a single piece that replaces rigid link mechanism [7].

The manufacturing of single piece, complaint mechanisms of medium size devices, is done using injection molding, rapid prototyping technology and method of extrusion [8], or by the use of techniques like silicon surface electroplating and micro machining. Even though the efforts in designing and analyzing the compliant mechanisms are very complex, still it is in practice because of its numerous advantages [9].

Most of the present designs are inherited on designer's instinct and knowledge of the current compliant mechanism that must be achieved without the assistance of a recognized synthesis method [10]. Several trial and error repetitions using finite element models the desired mechanism performance is obtained [11]. Normally, the Kinematics-oriented tactics and Structural optimization centered tactics are the two well-known methods available for the compliant mechanisms systematic synthesis [12][15]. Moreover, spring lever model and spring-mass lever model of Non-dimensional analysis with building block using complaints ellipsoid and instant centre (IC) method techniques are analyzed. Transferring an input force and displacement at any part to an output and displacement at another port complaint mechanisms becomes flexible mechanisms [16].

Compliant Mechanism are joint less structure, so no need of assembling and rubbing between two parts. The friction as seem at the joints at rigid body mechanism is absent [17]. Compliant Mechanism used in various applications, because they are cheaper, reduces the wear and tear and no need for lubrication and it also reduces total number of parts required to accomplish a specific task .Compliant Mechanism has advantages of cost reduction and increased performance and simplified manufacturing process.

Increasing performance includes increases it reliability in reduced wear, weight and maintenance Compliant Mechanisms are applicable in various fields such as handle tools, robotics, medical, and electronics and for various reasons [18].The main objective of the study is to explore the development of Compliant Mechanism concept on automotive compliant design with the help of topology optimization.

II. DESIGN OF ACTUAL CLUTCH FORK USING TOPOLOGY OPTIMISATION

APPROACH

Topology Optimization is a tool that assists the designs in the selection of suitable initial structure of topology by removing (or) redistributing material of structural domain [19] and the material of each element should take the value of 0.1 or either 0.5.The designs of topology is also treated as a layout optimization problem to search of the material arrangement and connecting with in a design domain. The design domain must me break down in such a manner so it can be paramaterialised and mathematically represents in a systematic fashion. The size and geometry of a given clutch fork can be further optimized to improve functional performance.

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The user needs to define the structured problem (material parts, FE Model, loads etc and the objective function (i.e. the function to minimized or maximized)

Figure 1. Actual clutch fork

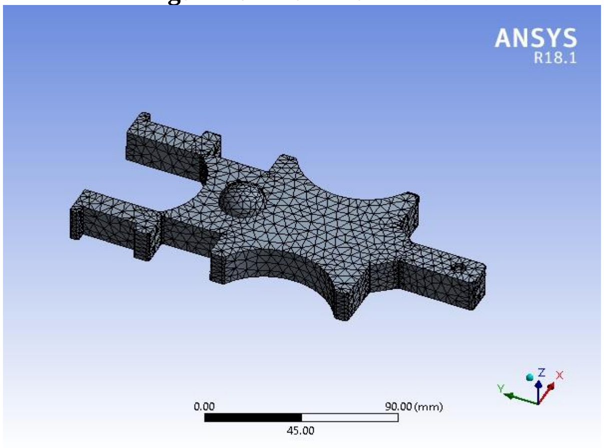

Figure 2. ***The 3D Meshed Model of Clutch Fork***

At present, the work is being carried to create, initial topology domain, specification, maximum possible volume of the material domain and to study the input location, constraints and optimization. Here, the draw direction option is used as a manufacturing constraint [20]. In this way the material layout can be produced and can be oriented to a particular direction. The other option is used for the study of one plane symmetry. Longitudinal symmetry is defined on the part for topology optimization. The optimization target is maximization of the stiffness with a volume reduction of fork to 50%.The optimized material mesh distribution is showed in Figure2.Toplogy optimization as a leaning to create the design proposals, as the material is accumulated in the outer border in the areas of design space .The next step is development of new clutch fork shape from the results of topology optimization.

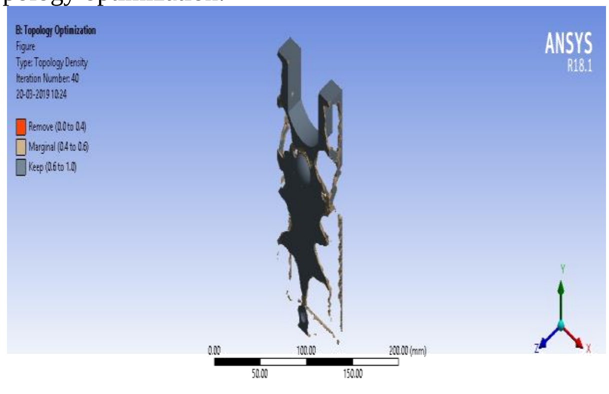

Figure 3.***Topology optimized domain of actual clutch fork***

III. REDESIGN OF MODERNIZED CLUTCH FORK BASED ON THE RESULT OF TOPOLOGY OPTIMIZATION

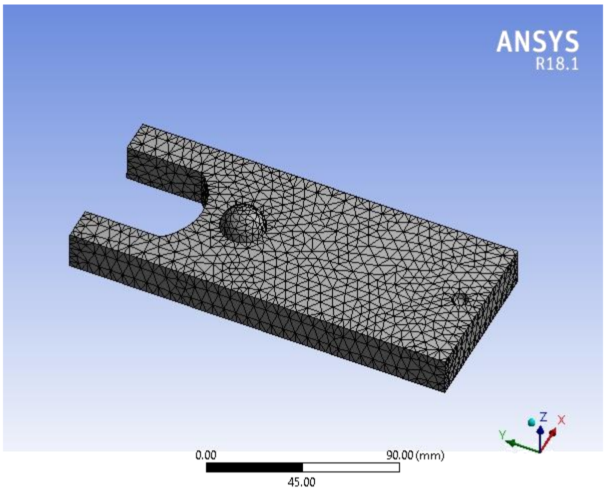

Figure 4. Redesign of new clutch fork based on the results of topology optimization.

Figure.4.shows the new geometry of clutch fork from the results of topology optimization. Stress analysis verifications are performed accurately to predict the operation of new design

IV. ANALYSIS OF COMPLIANT MECHANISM

The dimensional data of modernized clutch fork is gathered. Modernized clutch fork design will be used as a datum for reference. Clutch fork is modeled with dimensional data for actual dimension, size and shape. Topology optimized model with the reference of the datum size and shape the modern compliant clutch fork is designed with in the designs space within the set of loads and boundaries.

In the modernized clutch design 50% mass or weight has been reduced by topology optimization approach. The conventional topology optimization formulation uses a finite element method (FEM) to evaluate the design performance. Using either gradient-based mathematical programming techniques such as the optimality criteria algorithm and the o non gradient-based algorithms such as genetic algorithms design is optimized . Structural analysis is done together for datum and compliant clutch fork design .Figure5. Shows Cast iron has been selected to the datum and Figure6. Polypropylene [ABS Plastics] has been selected to compliant clutch fork and is referred as Design A. All the boundary conditions and loadings followed the actual working conditions of exists car clutch fork. Assumption actual force 6N, 20N is applied at back and centre of the clutch fork, 30N is applied as bearing load. Master CAM is used as to transfer all the shape information of the design the CATIA. The experimental model was used to observe the function and movement of clutch fork. Simple testing is done together for the compliant and actual clutch fork. The reason is to prove the compliant clutch fork perform equally with the actual clutch fork.

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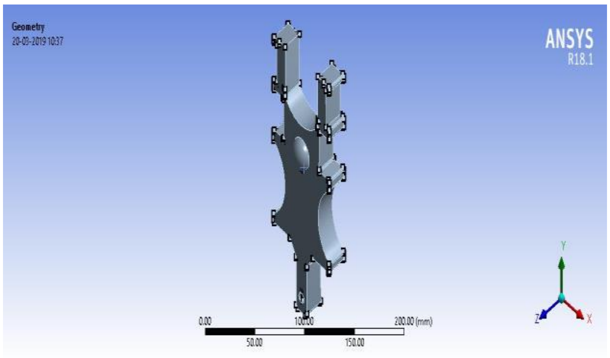
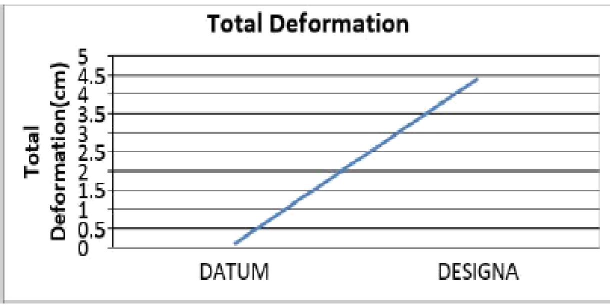


Figure 5. Datum design of optimized clutch fork



V. RESULTS AND DISCUSSIONS:

MASS OF DATUM & DESIGN A:

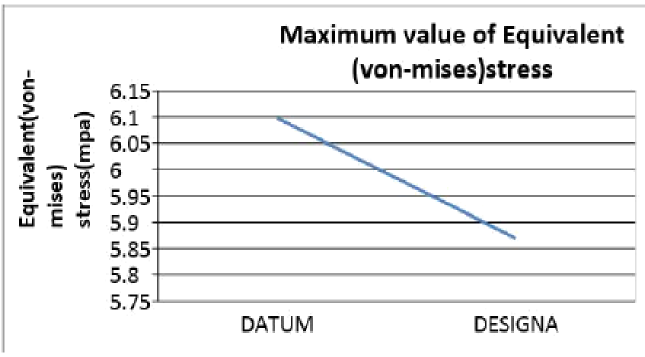


Figure.7.*Mass of Datum and Design A*

Figure7.Shows the masses of both datum and complaint clutch fork .As can been seen, the mass of design A is the lowest with 40g compare with Datum. Design A is assigned with ABS plastic material is more lighter compare with Datum as it is assigned with cast iron material .However lighter clutch fork is needed to maintain it function without compromise on the mechanical strength

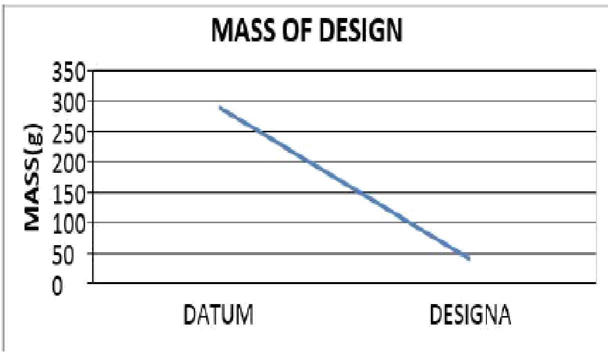


Figure 8. *Equivalent stress (Von-Misses stress) of Datum*

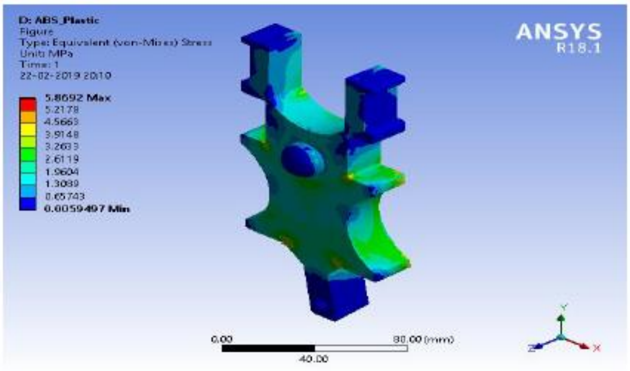


Figure 8. *Equivalent stress(Von-Misses stress) of Complaint Clutch Fork*

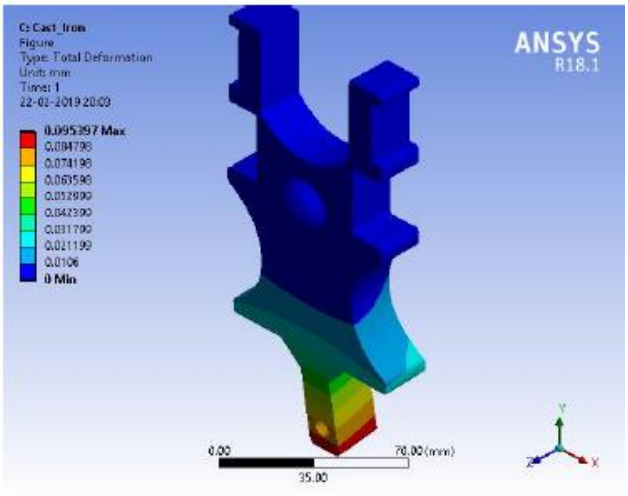


Figure 8.1.Stress distribution on Datum and Design A

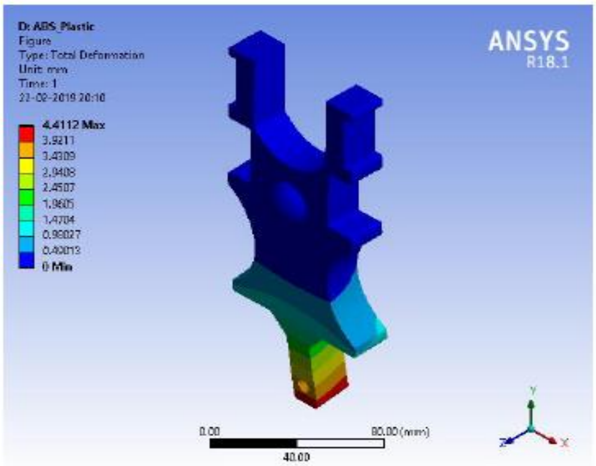


Figure.9.Total Deformation of Datum

Figure8.1. shows the stress distribution on clutch fork. Design A has the lowest value of the Maximum equivalent (von-mises) stress with 5.8692 MPa. This is much better than comparing to datum design with 6.0977 MPa. Maximum stress is an important criterion in design selection because failure occur at the area where the higher stress concentration, with the applied load .

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From the analysis results, Design A is the appropriate design for complaint clutch fork

Design A has the highest value of total deformation compare with the datum. At the end of clutch fork highest deformation is occurred. The fork with highest deformation seems like flexible and will impact the mechanical strength of the design.

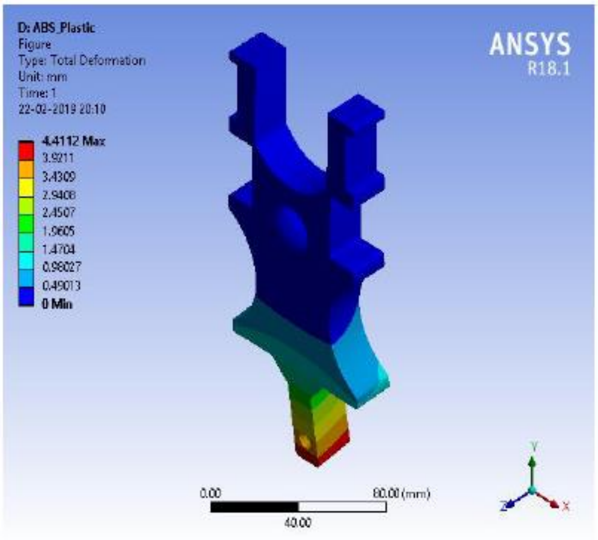

Figure 9.1.Simulation results of total deformation; Datum and Design A

Physical testing:

The appearance of experimental model is almost same as datum only size and mass is reduced. The material used is also different with the compliant clutch fork. The polymer based materials are good with complaint design are potentially to replace the cast iron based clutch fork due to equal functioning.

VI. CONCLUSION

Complaint mechanism by topology optimization is a great design approach for reducing the mass and number of components while maintaining the functions of modernized clutch fork. The complaint clutch fork met the functional requirement and mechanical strength as actual clutch fork .Based on simple testing the compliant clutch fork appearance and performance is quite same as datum. It also has good deformation and equivalent stress which maintaining structural stiffness

Besides reducing the mass of clutch fork, it also supports the design for no assembly concept. Single part results no assembly needed.So,it directly reduce the production cost while using polymer materials decrease material cost compare with the cast iron or steel based clutch fork. Polymer based materials are relatively cheaper than cast iron or steel based materials.

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