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Finite Element Analysis and Experimentation of Carbon Fiber Chain Drive

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Abstract

Chain drives are most important systems used in industry to carry the products and to transmit the power. But limitation is the chain drive suffers premature elongation due to wear and so that the costs of production will increases and ultimately the cost of operations also increases. In case of power transmission chain, the major factor affected on failure of chain is tensile load. It will be helpful to reduce the cost and time of production related to chain assembly of above said industries. The power transmission chain is used to transmit the power which deals with different load conditions. This causes wear and tear of components of chains and hence unexpected failure and costly production. In present work the study of different failures of chain links under different loading conditions using Mild Steel will be done. It was determined that maximum amount of weight of chain drive is covered by outer link and inner link. The chain is analyzed using Hyper-mesh and ANSYS software. The static loads are applied on the chain drive and analysis is carried out. The test is carried out to check the conformance of the existing design. The chain drive is optimized by changing it to carbon fiber material. Based on these results, best feasible design solution is proposed and validated experimentally.

Keywords- Power Transmission Chain, Chain Link, Tensile Loads, Composite Material Carbon Fiber, FEA Analysis

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I. INTRODUCTION

The chain is most suitable component, which transmit the power by means of tensile forces. It is used to transmit the power and convey the products. In general for power transmission we are using chain, gear or belt drive. But usually chain is most economical part of power transmission machines at low speed having large loads. However, it is also possible to use chain drive system for high speed conditions like automobile engine camshaft drives. This can be accomplished by devising a method of operation and lubrication. Generally, there is lower fatigue strength in chain and gear system, but not in the belt. Besides, if a gear tooth breaks, the gear will stop at the next tooth. Chain is more suitable for continuous running and power transmission with minimum torque fluctuation.

Most of the cases chain drive used are under tension due to which it causes failure of chain assembly. This is now major problem for automobile sector. Also the performance is proportional to the power to weight ratio of the vehicle. Hence weight reduction of chain link is necessary. The problem will solve either using composite material or method of construction.

A Composite materials is the combination of materials that are mixed together to achieve specific structural properties. The composite individual materials do not dissolve or merge completely, but they become an entity. The properties of composite more superior than the properties of the individual from which it is constructed.

Following are the properties that can be improved by forming a composite material:

- Strength -Fatigue Life
- Stiffness -Temperature-Dependent Behavior
- Corrosion Resistance -Thermal Insulation
- Wear Resistance -Thermal Conductivity
- Attractiveness -Acoustical Insulation
- Weight

A. Fibers

Fibers occupy the largest volume of fraction in laminate composite. The sheets with different orientation of high strength directions are stacked and glued together and producing more isotropic strength in the plane. Fibers are the principal component in a fiber-reinforced composite material. The strength of fiber reinforced composite are depend on fiber length and its orientation with respect to the stress direction.

B. Carbon Fibers

Carbon fiber provides more circumstances for development of PMC's as advanced structural engineering material, as compare to other. Carbon fiber commercially available with variety of tensile moduli ranging, that is for low side it is 207GPa and for high side it is 1035GPa. In general, the advantages of carbon fibers are their exceptionally high tensile strength to weight ratio. It also has high tensile modulus with weight ratio and high fatigue strength.

II. REVIEW OF PAPERS

1) Nikhil S. Pisal, V.J. Khot, Swapnil S. Kulkarni, "Design and Development of Motorcycle Chain Links by Using C.A.E. Software", International Journal of Scientific Research and Management Studies (IJSRMS) ISSN: 2349-3771 Volume 2 Issue 4, pg. 175-183.

The new motorcycle to be launched in the automobile market needs to be ensured for safety and efficiency. Chain drives being efficient means of power transmission are preferred for this product. The limitation, of course, was being catastrophic failure at virtually no prior notice. At high speed, accidents are very likely in case of failure in the chain link. The problem needs to be looked into and investigated for identifying causes for failure. Similarly, upcoming variants to be incorporated with the new solution to eliminate such challenges in the future. The design for the chain would be subjected to F.E Analysis as an Analytical Methodology to find the effect of loads (tension) on the link. The link being a `unit' of the existing chain would be assessed for performance while tensile loads are exerted at both its ends. Safe loads would be determined and the design tested for safe use in the Automobile. The problem for this work is being evaluation of the design using Analytical methodology followed by experimentation to validate it. An existing chain link would be used for benchmarking the research work. Finite Element Analysis tools like Hyper Mesh and ANSYS are suitable to find the performance of the link under tensile loads. Recommendation over the best suited geometry or material would be presented to conclude the work.

The design for the chain would be subjected to F.E Analysis to find the effect of loads (tension) on the link. The proposed method utilizes software in the FEA domain for analysing the effects of the variation in the values of the design parameters influencing the performance criterion. As the seamed bush and seamless bush, changed design parameters of inner links and outer links, roller, bush, thickness is increases. If the thickness of link plate is increases the rate of tensile stress decreases. Consequently weight with increases in the thickness of the link plate can be realized using a higher strength of material. The FEM method is used to analyse the stress state of an elastic body with a given geometry, such as chain link.

2) Shrikant Annasaheb Choudhari, Prof. G. E. Kondhalkar, "Motorcycle Chain Analysis And Development by CAE Software", International Journal of Engineering Science and Computing, July 2016, ISSN 2321 3361.

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3) Amol J. Kadam, Dr. Shailesh V. Deshpande, "Design and Analysis of conveyor chain link using composite material: a Review", Special Issue, Recent Trends In Mechanical engineering, VVPIET, Solapur, Maharashtra, India, February 2015.

The basic aim of this review has been conducted on the most of the time conveyor chain is under tension which causes failure of chain assembly which is the major problem for industrial sector. Causes of this failure are improper design. It is important to study the influence of these parameters. All these parameters can be considered simultaneously and chain link design optimally. Optimization is the process of obtaining the best result under given circumstances in design of system. In optimization process we can find the conditions that give the maximum and minimum value of function. In this study a shape optimization process is used for the design of roller chain link for minimization of failure modes. This process various design variables, such as wall thickness of link, breaking area of link and shape of the link. While deciding the shape optimization of roller chain link raw material plays important role, so it is necessary to decide raw material.

The literature review presents that design optimization of link, wear mechanism, stress analysis is widely done by FEA & FEM and failure of link plate. Chain link consider different design parameters and behaviour of failure. FEA apply in mechanical element and link, we find in which the parameters are affect to its failure. FEA based simulated model gives approximation of simulated parameters and generate the mesh FEA model gives the result respect number of nodes and elements. Also the review presents that for weight reduction and effectiveness of chain operation, the focus will be on using alternate polymer material & design parameters.

4) Mr. BragePrashantRavindra, Prof. V. H. Waghmare, Mr. S.D.Chavan, "Roller Chain Link Plate Design Based on FEA", International Journal on Recent and Innovation Trends in Computing and Communication, Volume: 2 Issue: 12, ISSN: 2321-8169.

Most of the time conveyor industry uses chain link assembly; the scope of this paper is to find out the areas where we can increase strength of chain, by reducing its stress concentration with reduction in weight. The paper investigates into various manufacturing features for the same. Finally Finite Element Analysis (FEA) has been used to check out the experimental and software outcomes. Later lot of effort has previously been ended in other constituents, in this development the concentration has been tapered down to specific component of chain. Inside the outer link, most dimensions in the manufacturing are parametrically well defined. In this paper we measure the impact of change in different constraint and manufacturing methods of outer link on the stress in the structure and see if material saving is thinkable or not.

The weight saving will have a major control on cost of the chain, and more principally with a lighter chain, the cost savings during procedure will also be significant. Based on the above literature and methodology used in this paper, it is detected that though this optimization looks minor on its individual, it must be well-known that in a typical industrial application, thousands of such links will be required.

5) J. Kadam, Dr. S.V. Deshpande, "Design & Development Of Conveyor Chain Outer Link By Using Composite Material", International Journal Of Innovations In Engineering Research And Technology, ISSN: 2394-3696 VOLUME 2, ISSUE 12, DEC.-2015.

In production or assembly lines roller conveyor chains are generally used where individual large objects need to be conveyed. Typical applications of roller conveyors are carrier conveyors for the transport of steel coils in a steel plant or slat conveyors that carry objects. A slat conveyor consists of two or more endless strands of chain with attached non interlocking slats or metal flights to carry the material. Other examples are conveying pallets, tree-stumps or even whole cars. Motor capacity of conveyor depends on the weight of chain in chain conveyor system. It was determined that maximum amount of weight of chain conveyor is covered by outer link and inner link. In this paper, we concentrated on only outer link and weight optimization of link by using composite material (Glass Fibre & Carbon Fibre) to reduce the power requirement of conveyor.

Finite Element analysis was performed to achieve the stresses and deformations and in results, it is found that, there is a maximum deformation of 0.03699mm in the mild steel link and in glass fibre with15 mm thickness is 0.044641mm. From the static analysis results, we see that the von-misses stress in the mild steel is 131.31MPa. And the von-misses stress in glass fibre is 53.692MPa. Glass fibre link plate can be suggested for alternative for the steel link plate from stress and stiffness point of view. A virtual study has been made between steel and composite link with respect to strength and weight. Fatigue life of both glass fibre link and carbon fibre link is higher than the mild steel link. As per the UTM test performed, the maximum load carrying capacity of the glass fibre link is 16000 N which is well above the defined load. Weight optimization is achieved 24 % with glass fibre, the weight of the glass fiber link is 0.2407 kg and that of mild steel link is 0.3135 kg. It must be noted that, in typical industrial application thousands of such link will be needed. Thus, the weight optimizations will have significant impact on cost of the chain and power consumption by motor.

III. METHODOLOGY

A. *Literature Survey*

Using the knowledge from literature review, we can know how the CAD model is to be prepared. The conditions required for applying various constraints and how the loads are applied is briefed about in the technical papers referred.

B. *CAD Model Generation*

- Getting input data on dimensions of chain links from market.
- Creating 3D model in CATIA.

C. *Determination of Loads*

Determination of different loads and boundary condition acting on the component by studying various ref papers, and different resources available.

D. *Testing and Analysis*

- Meshing the CAD model and applying the boundary conditions.
- Solve for the solution of meshed model using ANSYS

E. *Re-Design, Analysis and Results*

- Making changes in CAD model for optimization.
- Carrying different iteration by changing material and topology based on ANSYS results.
- Check the maximum stress ensuring it is well within the safe region.

F. *Fabrication, Experimental Validation and Result*

- Fabrication of prototype.
- Suitable experimentation and comparison with present chain links.
- Validation of result by comparing with software results.

IV. DESIGN AND ANALYSIS OF CHAIN LINK

A. Design and Analysis of Chain Link

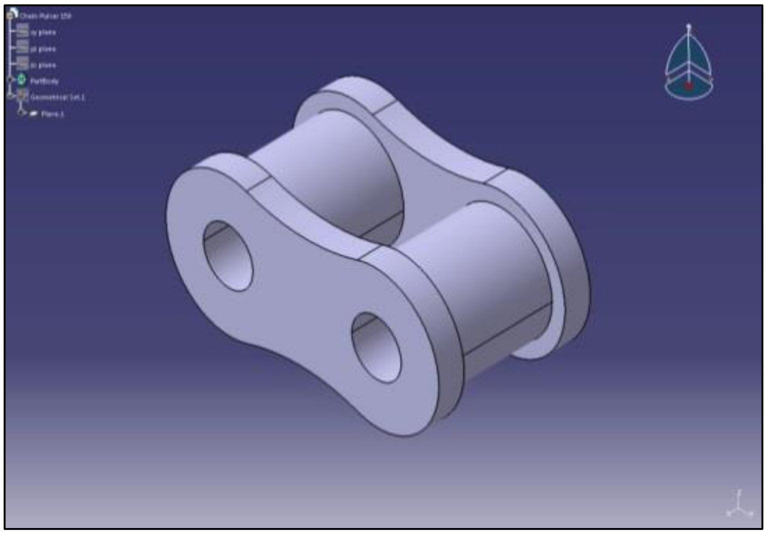

Fig. 1: CAD model of inner plates with bushes

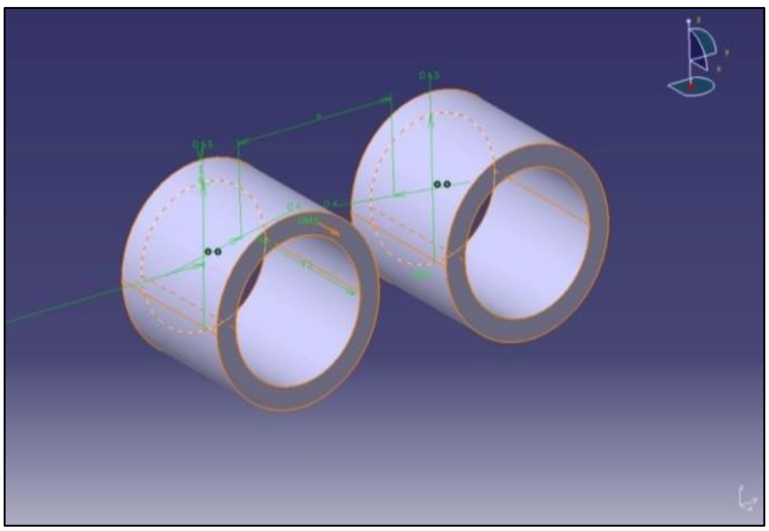

Fig. 2: CAD model of rollers

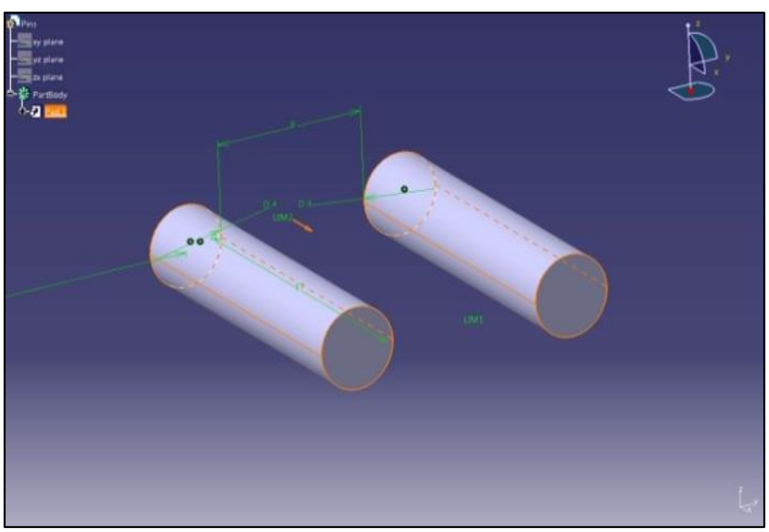

Fig. 3: CAD model of pins

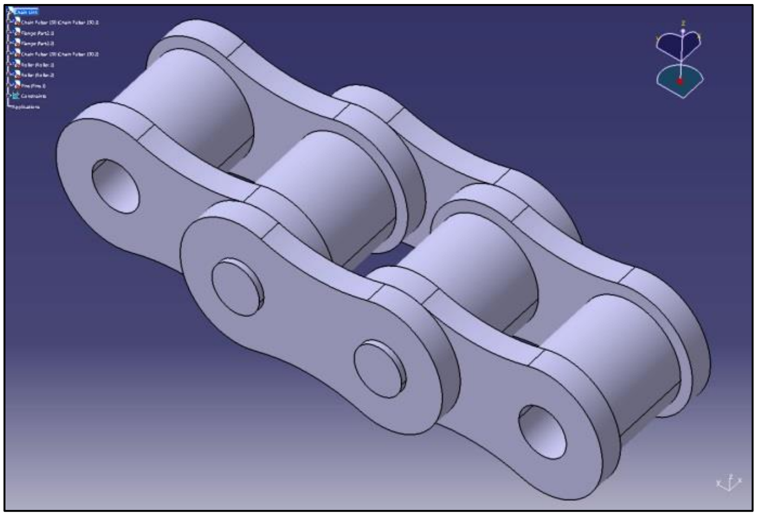

Fig. 4: Chain Link Assembly

V. TESTING AND ANALYSIS OF LOADS AND BOUNDARY CONDITIONS

Table 1: Bajaj Pulsar 150cc Technical Specifications

Specifications of Bajaj Pulsar 150cc	
Type of Engine	*Single Cylinder, 4 -Stroke engine*
Displacement of Engine	*149CC*
Maximum Power	*11.08 kW@9000*
Maximum Torque	*12.28Nm@6500*
Transmission	*5-Speed Constant Mesh*
Weight	*144kg*
Tyre size front	*2.75 -17"*
Tyre size rear	*110/90-17"*
Primary Reduction	*3.47*
1stGear	*2.92*
2ndGear	*1.88*
3rdGear	*1.38*
4thGear	*1.08*
5th Gear	*0.92*
Final Reduction	*2.93*
Drive sprocket no of teeth , Z1	*15*
Driven Sprocket no of teeth, Z2	*44*
Driven Sprocket Diameter (PCD)	*170 mm*

VI. BOUNDARY CONDITIONS

The chain of two wheeler operates under the tensile loading condition. The maximum tension in the chain will be experienced at maximum torque condition of the engine.
Overall Gear Ratio = G = Primary reduction x First Gear Ratio x Final Reduction
Maximum Engine Torque (Te_{max}) = 12.28Nm @ 6500
Torque available at rear (driven) sprocket (Ts) = Te_{max} x G
Tension in the chain (F_{max}) = Ts / Rs = 4294.12

Table 2: Existing Material: AISI 304 Stainless Steel

Property	*Value*
Young's Modulus,	*200 GPa*
Poisson's Ratio	*0.29*
Density	*8000 kg/m^3*
Yield Stress	*215 MPa*
Ultimate Tensile Stress	*505 MPa*

VII. BOUNDARY CONDITIONS APPLIED TO THE CHAIN LINK ASSEMBLY

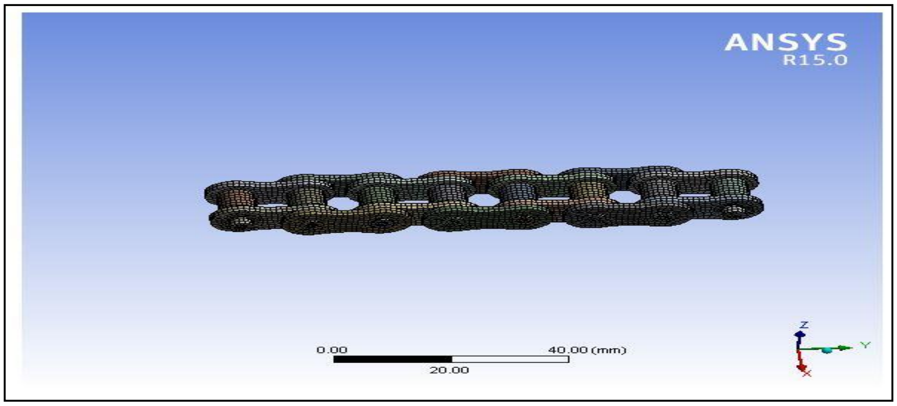

Fig. 5: Meshed model of chain link assembly

The one end of the link is given with fixed support and the force 4295N is applied on the other end.

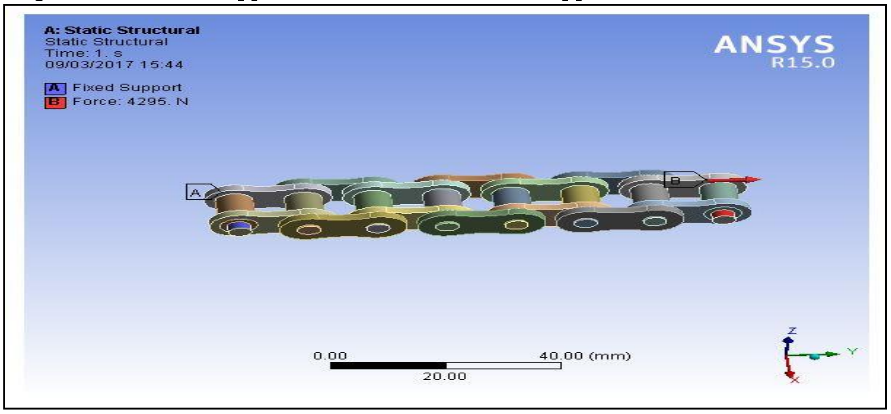

Fig. 6: Boundary condition applied in ANSYS

A. Post-processing

The applied model of meshed and boundary condition is imported to the solver. The process of analysis commences after applying run in the solver software. With respect to applied boundary conditions software first calculates the deflections. The strain can be easily calculated on the basis of deflections. After calculating the strain we can calculate the stress value, as we know the modulus of elasticity. The result is displayed and accordingly modifications are suggested. The suggested modifications are according to high stress region obtained. In case the stresses are beyond the permissible limits then changes occurs such as change in thickness of components or additions of ribs and change in material etc. are made according to suitable conditions. The calculations of stress depend on failure.

B. Von-Mises Stress

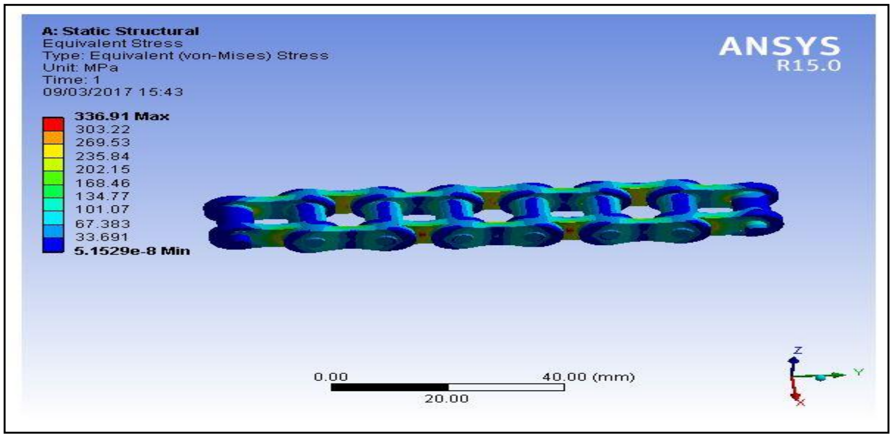

Fig. 7: von-mises stress for Chain link assembly Stress value for chain link is 336.91MPa which is below the critical value. Therefore, design is safe

C. Displacement

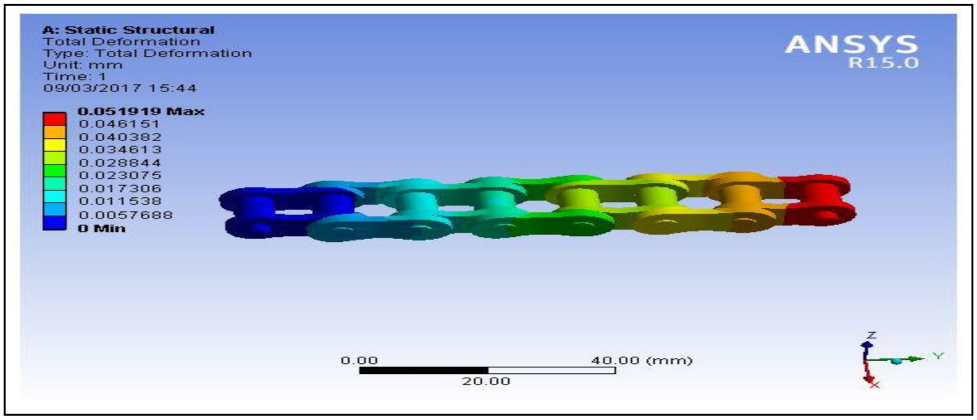

Fig. 8: The maximum displacment is coming out to be 0.0519 mm which is less

D. Closure

The stress and deformations in the existing chain link assembly are very less. Hence we have lot of scope to optimize the spur gear design. Initially we will be using carbon fiber as a material for plates in chain link assembly and the FEA will be done with same boundary conditions.

VIII. RE-DESIGN, ANALYSIS AND RESULTS

A. Boundary Conditions Applied to the Chain Link Assembly

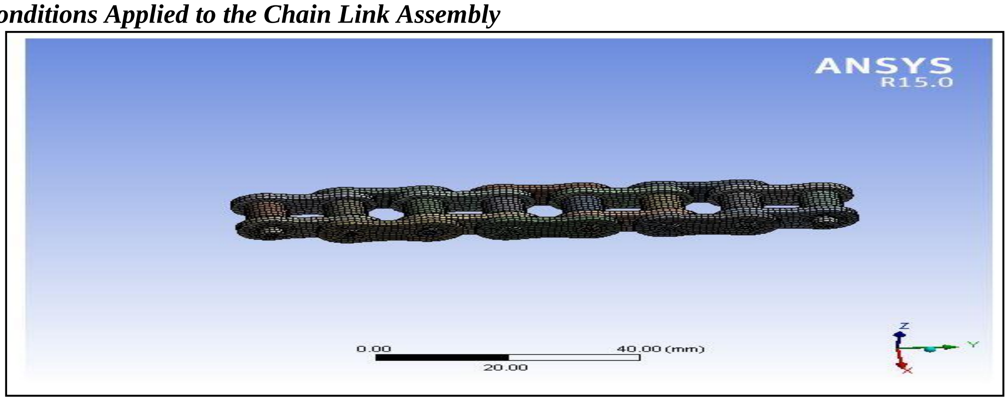

Fig. 9: Meshed model of chain link assembly

The one end of the link is given with fixed support and the force 4295N is applied on the other end.

Table 3: Fiber Orientation will be for 2mm thickness Plate (Carbon Fiber)

Sr. No.	*Fiber Orientation Angle*	*Thickness*
1	*45*	*0.5*
2	*-45*	*0.5*
3	*45*	*0.5*
4	*-45*	*0.5*

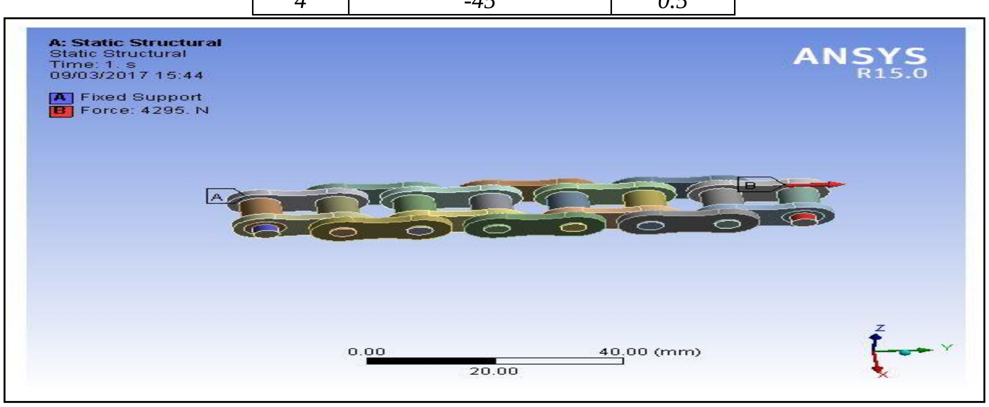

Fig. 10: Boundary condition applied in ANSYS

B. Post-Processing

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C. Von-Mises Stress

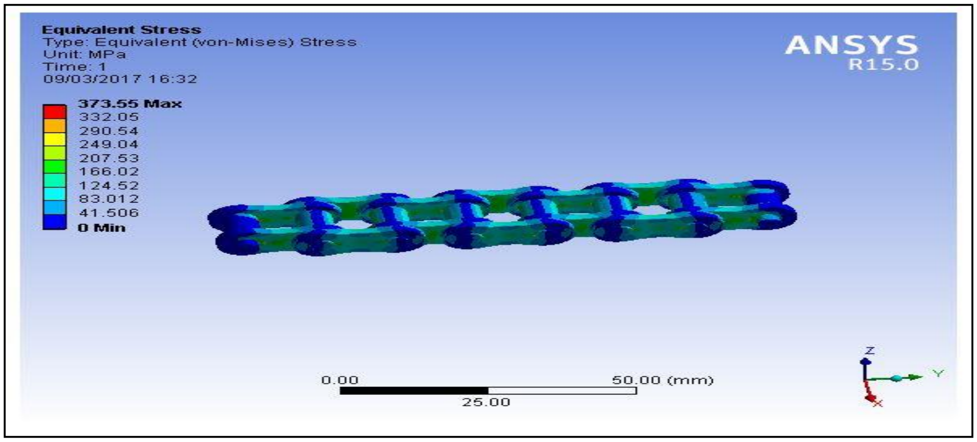


Fig. 11: von-mises stress for chain link assembly Stress value for chain link is 373.55.91MPa which is below the critical value. Therefore, design is safe

D. Displacement

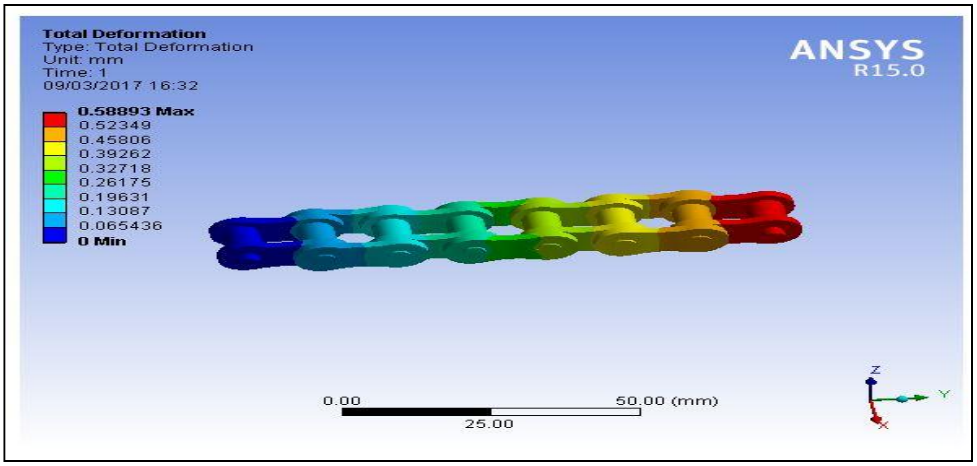


Fig. 12: The maximum displacement is coming out to be 0.58 mm which is less

E. Closure

The stress and deformations in the existing chain link assembly are very less by using carbon fiber as a material. Hence the design is in the safe condition.

Finally the most optimized gear will be manufactured and the FEA results will be validated experimentally.

Table 4: Comparison between materials

Sr.No.	*Material*	*Stress (MPa)*	*Deformation (mm)*	*Weight (Kg)*
1.	*AISI 304 Stainless Steel*	*336.91*	*0.0519*	*0.062*
2.	*Carbon Fiber*	*373.55*	*0.588*	*0.036*

IX. EXPERIMENTAL VALIDATION

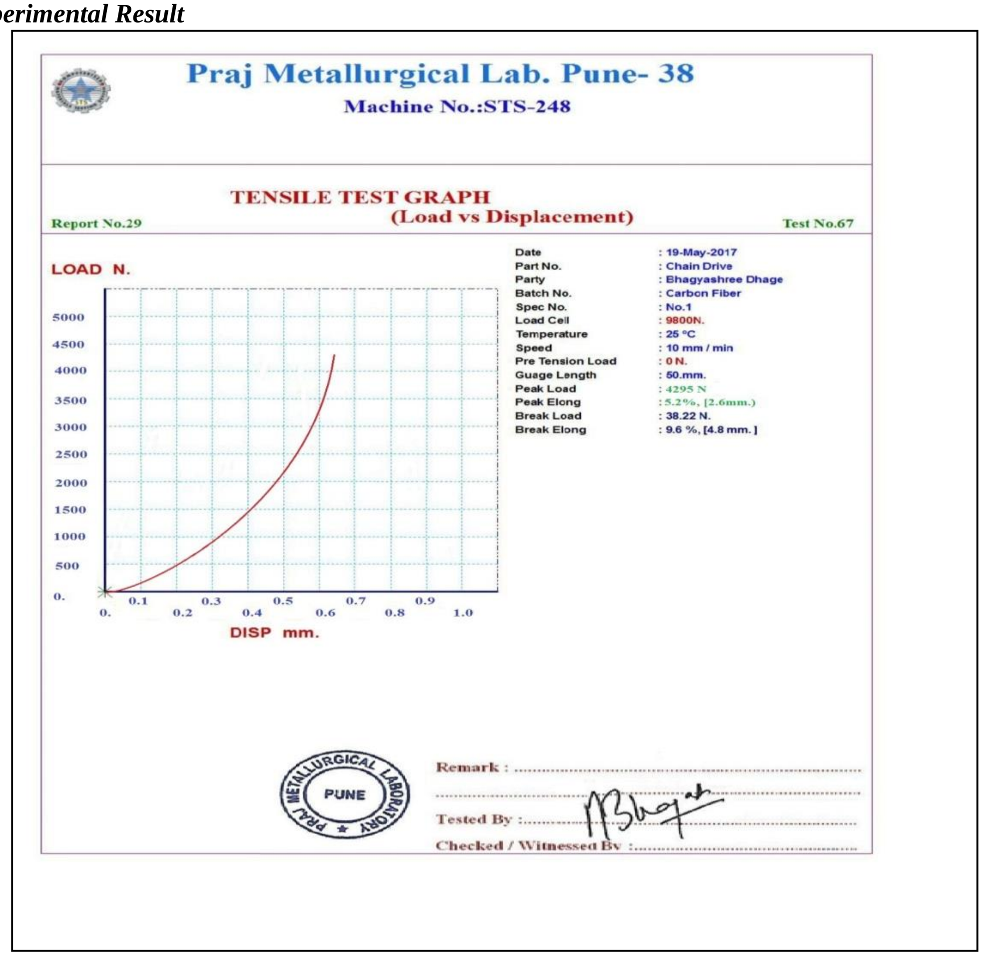
- Fabrication of prototype.
- Suitable experimentation and comparison with present chain links.
- Validation of result by comparing with software results.

A. Experimental Setup

Fig. 13: Image of UTM

The specimen is placed in the UTM machine between grips and extensometer. If necessary it can automatically record the change in gauge length during the test. If an extensometer is not fitted then the machine itself record the displacement between crosshead on which the specimen is held. This method is used not only to measure the length of specimen but also all other extending elastic components. Its drive system includes any slipping of specimen in the grips. When machine starts it applies increasing load on specimen. During the test the control system and its associate software records the load, displacement or compression of the specimen.

B. Graph of Experimental Result



C. Results

As per above result deformation will be 0.63mm

Table 5: Comparison between FEA and Experimental Result

Sr. No.	*Deformation*		
	FEA Result	*Experimental Result*	*Error %*
1.	*0.588*	*0.63*	*6.66*

Table 6: Percentage of weight reduction

Sr. No.	*Weight(kg)*	*Percentage weight reduction*
Stainless Steel	*0.062*	*41.93%*
Carbon Fibre	*0.036*	

X. CONCLUSIONS

The steel chain link assembly plate has been replaced by carbon fiber plates. The Finite Element Analysis has been successfully performed for both stainless steel and carbon fiber materials. The comparison in the above table for both materials has been listed. There is weight reduction after replacing carbon fiber plates from stainless steel plates. There is slight increase in the stress and deformation after changing material from existing to carbon fiber. Percentage weight reduction is 41.93%. Hence stresses are within the limits and Design is safe.

ACKNOWLEDGMENT

First and foremost, I would like to express my sincere gratitude to my guide Prof A. D. Diwate, for whom I have greatest amount of respect and admiration, He support throughout my time as a student in Mechanical Engineering Department, Bhivarabai Sawant College of Engineering and Research, And I specially thanks the backbone of my success & confidence lies solely on the blessing of my parents and my husband.

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