Life Cycle Prediction Analysis of Automobile Chain Link using Composites

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Abstract - *The scope of this paper is to study the behavior of chain under tensile fatigue loading. Chains in two wheelers have to deal with repetitive loading, This causes wear and tear of components of chains and hence unexpected failure. In present work the study of failures of chain links under tensile 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. In this project we performed, FEA analysis of the stresses in chain link and estimation of required breaking load as per given capacity of roller chain, finite element analysis of stresses in chain link and pin for traditional material and composite material using ANSYS. The chain is analyzed using Hypermesh and ANSYS software. The static loads are applied on the chain drive and analysis is carried out and then repetitive loading fatigue life is determined on same loading constraints. The chain drive is optimized by changing it to carbon fiber material by iterative method finding its optimum thickness. Based on these results, best feasible design solution is proposed and validated experimentally.*

*Key Words***: Chain drives, fatigue failure, Plastic deformation, carbon fiber, life cycle, composite material**

1. INTRODUCTION

As the new technology advanced 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, 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. The problem lies in fatigue failure rather than static loading, 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 repetitive loads (tension) on the link. while tensile repetitive loads are exerted at both its ends. The problem for this work 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 HyperMesh 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.

Using the FEA application a model is set up to investigate the impact of fatigue life static stress on a bicycle chain for different geometries. Plastic deformation is taken into account for defining safe working material and topology. Based on the simulation results the contribution of plastic deformation to lifetime restriction can be estimated. The results suggest that common high tension carbon fiber can be used for increasing life cycle. We have to use of composite material for chain out link to minimize the weight of link.

Scope of work

1. Weight reduction of the chain due to the use of composite material.

2.   Corrosion resistant chain, as composites are corrosion resistant.

3.   To study different composite material for bracket and study surface composition of composites for the same

4.   To perform experimental investigation for optimizing life cycle of the chain

5.   To design and analyze optimum solution for the chain link of chain drive in transmission under repetitive tensile load

2. Literature Survey:

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.

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tested for safe use in the Automobile. The problem for this work 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 HyperMesh 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 analyzing the effects of the variation in the values of the design parameters influencing the performance criterion. As the seamed bush and seamless bush, change design parameters of inner links and outer links, roller, bush, thickness of increases. If the thickness of link plate increase to the rate of decreases in tensile stress. Consequently weight with a increases in the thickness of the link plate can be realized using a higher strength of material. The FEM method is used to analyze the stress state of an elastic body with a given geometry, such as chain link.[1]

ShrikantAnnasahebChoudhari, 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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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 behavior 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.[3]

Conclusion from literature survey:

• By studying different papers and work done on it, we have come to know that the chain is the most important and critical part of the automobile transmission system. Currently used chains are susceptible to tensile failure as most study conveyed. But the scope of failure is not static condition it's a fatigue failure which is still a future scope of work in literatures hence our work scope will be on chain life cycle and optimization.

• As the performance is proportional to the power to weight ratio of the vehicle, weight reduction is necessary in the chain through material change to composite.

• Current design of the chain links must be studied and optimized for better design of chain links without compromising over its strength.

• New design must be able to withstand all of the loads it is going to undertake.

• Previous study didn't include life cycle prediction analysis and experimental validation.

PROBLEM IDENTIFICATION:

Failure due to repetitive loading (wear and tear).

Most of the time chain drive used is under repetitive tension which causes failure of chain assembly. This is found to be a major problem for automobile sector. Also the performance is proportional to the power to weight ratio of the vehicle. Hence weight reduction is necessary, As per research finding all earlier work focus on static analysis but a chain drive doest fail at static condition it fails after a term life of cyclic loading, hence to increase its life span our scope is to perform FEA and experimental investigation for life cycle prediction of automobile chain using composites

OBJECTIVES:

The main objective of the project is to predict cycle of existing chain link system used in 2 wheeler and to optimize it by using composite material intend to increase its life cycle.

And for that we will do design and analyze the optimum solution for the chain links of chain drive in transmission under fatigue tensile load and optimization using carbon fiber for the chain links.

METHODOLOGY:

- Problem Definition/Objective
- Background Research/ Literature Review
- CAD Model generation in CATIA V5
- Meshing in Hypermesh and applying loading and Boundary Conditions
- Simulation of model and Optimization
- CAD, meshing and re-analysis of optimized model
- Fabrication, Experimentation and Validation

TOOLS AND SOFTWARE USED: (As per requirement)

- CAD :
  Catia v5

- CAE :
  Hypermesh 14,
  Ansys 14

- MANUFACTURING:
  Turning Center, Drilling center, milling, SPM, bending, welding, grinder, Laser cutting etc.

- TESTING: (Approved Labs and Certificate)
  Fatigue Rig with DAS (Data Acquisition System)
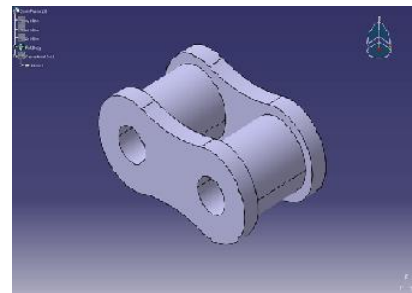
CAD Model Chain Link:

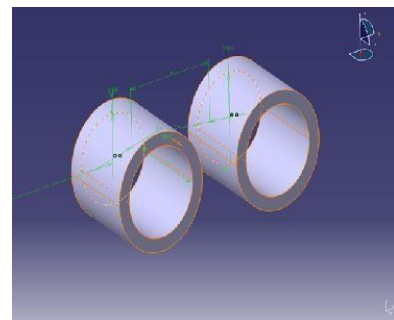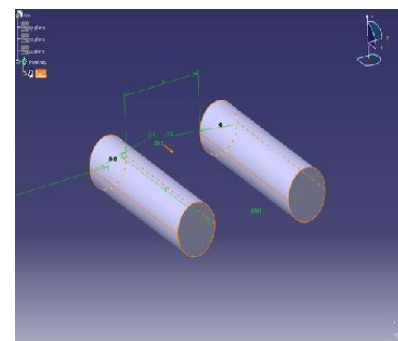Fig. CAD model of inner plates with bushes

Fig. CAD model of rollers
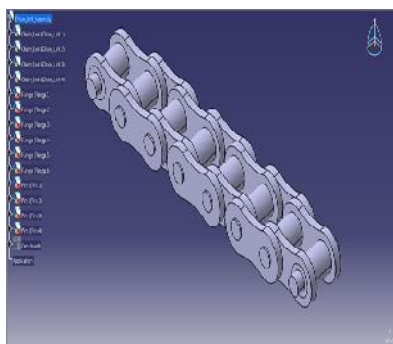

Fig. CAD model of pins

Fig. Chain Link Assembly

CHAIN LINK ANALYSIS USING CARBON FIBER

Basic Concepts of Composite Materials: Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. Various scientific definitions for composite materials can be expresses as follows;

- The word composite means made up of two or more parts. A composite material is one made of two other materials. The composite material then has the properties of the two materials that have been combined.
- The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. The key is the macroscopic examination of a material wherein the components can be identified by the naked eye. Different materials can be combined on a microscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes, macroscopically homogeneous, i.e., the components cannot be distinguished by the naked eye and essentially act together.
- Composites, which consist of two or more separate materials combined in macroscopic structural unit, are made from various combinations of the other tree materials.
- A composite is a structural material which co combining two or more constituents. The con are combined at a macroscopic level and are no in each other.
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resulting material is, for all practical p macroscopically homogeneous,i.e. the com cannot be distinguished by the naked essentially act together. The advantage of c materials is that, if well designed, they usuall the best qualities of their components or con and often some qualities that neither co possesses. Some of the properties that can be i by forming a composite material are:

- Strength -fatigue life
- Stiffness -temperature-dependent behavior
- Corrosion resistance -thermal insulation
- Wear resistance -thermal conductivity
- Attractiveness -acoustical insulation
- weight

Naturally, not all of these properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another, e.g., thermal insulation versus thermal conductivity. The objective is merely to create a material that has only the characteristics needed to perform the design task.

Composite materials have a long history of usage. Their precise beginnings are unknown, but all recorded history contains references to some form of composite material. For example, straw was used by the Israelites to strengthen mud bricks, the use of straw in clay as a construction material by the Egyptians.

Medieval swords and armor were constructed with layers of different metals. More recently, fiber-reinforced, resin-matrix composite materials that have high strength to weight and stiffness-to-weight ratios have become important in weight sensitive applications such as aircraft and space vehicles.

Modern composites using fiber-reinforced matrices of various types have created a revolution in high-performance structures in recent years. Advanced composite materials offer significant advantages in strength and stiffness coupled with lightweight, relative to conventional metallic materials. Along with this structural performance comes the freedom to select the orientation of the fibers for optimum performance. Modern composites have been described as being revolutionary in the sense that the material can be designed as well as the structure.

There are two building blocks that constitute two the structure of composite materials. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particulates,

flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel, epoxy reinforced with graphite fibers, etc.

Fibers:

Fibers are the principal constituent in a fiber-reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion\ of the load acting on a composite structure. Proper selection of the type, amount and orientation of fibers is very important, because it influences the following characteristics of a composite laminate.

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Fatigue strength and fatigue failure mechanisms
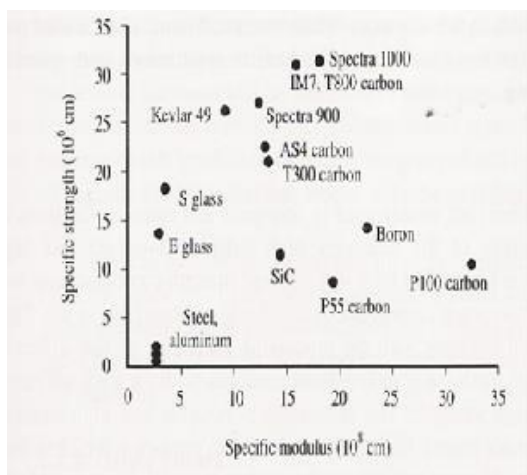- Electric and thermal conductivities
- Cost

Fig. - Specific modulus and specific strength for various engineering materials and fibers.

The various types of fibers currently in use are discussed in what follows.
- Glass Fibers
- Carbon Fibers
- Aramid Fibers
- Boron Fibers
- Silicon Carbide Fiber

Carbon Fibers:

Carbon fibers, more than all other fibrous reinforcements, have provided the basis for the development of PMCs as advanced structural engineering materials. Carbon fibers are commercially available with a

variety of tensile moduli ranging from 207Gpa on the low side to 1035 GPa on the high side. In general, low modulus fibers have lower specific gravities, lower cost, higher tensile and compressive strengths and higher tensile strain to failure than high modulus fibers. Among the advantages of carbon fibers are their exceptionally high tensile strength to weight ratios and tensile modulus to weight ratios, very low CTEs (which provide dimensional stability in such applications as space antennas) and high fatigue strengths. The disadvantages are their low impact resistance and high electric conductivity, which may cause shorting in unprotected electrical machinery. Their high cost has so far excluded them from widespread commercial application. Carbon fibers are widely used in aerospace and some applications of sporting goods, taking advantages of the relatively high stiffness to weight and high strength to weight ratios of these fibers. The structure and properties of carbon fibers are dependent on the raw material used the process conditions of manufacture. The manufacturing process involves the oxidation, textile precursors and pitch precursors. The most common textile precursor is PAN. Depending on processing conditions, a wide range of mechanical properties (controlled by structural variation) can be obtained, and fibers can therefore be chosen from this range so as to give the desired composite properties. Carbon fibers are commercially available in three basic forms, namely, long, continue tow, chopped (6-50mm long) and milled (30- 3000μm long). The long, continues tow, which is simply a bundle of 1000-160.000 parallel filaments, is used to for high performance applications.

Mechanical Properties	Units	Carbon Fibre
Young's Modulus, E_{11}	GPa	190
Young's Modulus, E_{22}	GPa	7.7
Bulk Modulus, G_{12}	GPa	4.2
Poisson's ratio, v_{12}		0.2
Density, ρ	Kg/m^3	1600
Tensile strength, σ_{uts}	MPa	1800
$S_{t1} = S_{c1}$	MPa	870
$S_{t2} = S_{c2}$	MPa	54
S_{12}	MPa	30

Table: Material properties of carbon fibers

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.

Comparison Table

Material	Stress (MPa)	Deformation(mm)	Weight (Kg)
AISI 304 Stainless Steel	336.91	0.0519	0.062
Carbon Fiber	373.55	0.588	0.036

Result and Comparison Table

Material	Stress (MPa)	Deformation (mm)	Life Cycle	Weight (Kg)
AISI 304 Stainless Steel;	336.91	0.0519	1000000	0.058
Carbon Fiber	373.55	0.588	1200000	0.036

Conclusions

• The steel chain link assembly plates 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 material 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, but under safe limits
• Percentage weight reduction is 37.9 %.

• Hence stresses are within the limits and Design is safe.
• Life cycle is improved by 20%

References:

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.

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