Experimental and Numerical Investigation of Carbon Fibre Chain Link

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***Abstract*— Observing the literature available on the topic, we have noted the absence of analysis of roller chains manufactured from carbon fibre. We plan to do a comprehensive study on the topic, noting the increase in the use of carbon fibre in different industries along with its advantages.The chain is subjected to a practical fatigue testing followed by a F.E. Analysis to find effects of load and further compare and verify the practical results.**

Results thus obtained are used to delineate the predicted advantages of the modified chain over conventional steel one. It will thus be shown that carbon fibre chain will be more feasible in application.

Use of computer software can help us in the optimization of the results and find out the percentage change in the practical and software analyses. Since some work has already been done in other mechanical analyses, in this paper the focus has been narrowed down specifically to fatigue analysis only. We have made use of composite material for chain link to minimize the weight of link.

***Keywords*— Chain Link, Fatigue**

I. INTRODUCTION

A Chain is a machine component used to transmit power and motion by means of tensile forces. It is similar to a belt drive transmission system with the exception that belt drive uses friction whereas a chain drive is a purely positive engagement transmission. Chain drives have been in use in the automotive segment for quite some time. In motorcycles though, they are used for final transmission from the gearbox to the rear wheels, on a very large scale. Most of the motorcycles have chain transmission with a few exceptions using belt or shaft drives.

The use as a main drive component makes the chain a critical component for the vehicle. This makes is important for us to study about them and come up with new ideas to tackle with their limitations. Motorcycle transmission ultimately affects the performance and the efficiency of the vehicle, and also plays a vital role in smooth operation and transfer of power without much loss.

All chains 'stretch' during their lifetime and eventually need replacing. Chains don't stretch in the same way elastic bands do – they get longer because the metal in the links gradually wear away and makes the overall length of the chain will increase. If there's too much slack, the chain will jump around lots whenever you change speed

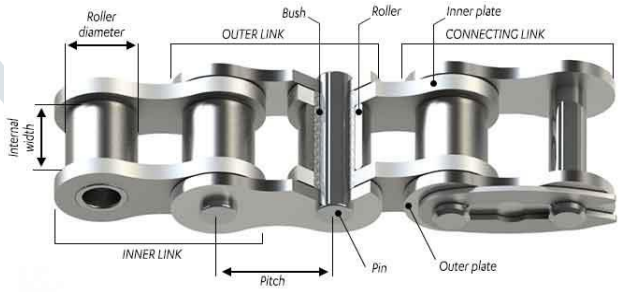

Fig 1.1: Construction of Chain

Advantages of Chain drive-

- They are lighter in weight than the shaft drives.
- Because of their design, the chain drives tend to absorb shock loads from sudden changes in speed of vehicle as sudden acceleration, deceleration; and also shocks resulting from surface irregularities.
- They provide better fuel economy.
- Final drive ratio can be changed by replacing sprockets with different number of teeth. This might be costly though a feasible option in case a need presents itself.
- 100% positive transmission unlike the belt drive. This consequentially provides a better option for high performance vehicles.

Disadvantages of chain drive-

- Requires more maintenance than is required for belt or shaft drive. The shaft drive mostly doesn't require any upkeep and has better longevity and durability for long periods of time. Chain drive requires oiling, cleaning and tensioning. Belt drives only need tensioning check.
- Cannot be used in a rough terrain usually with dirt, mud and water which can render the oiling useless and the chain will run without lubrication. Shaft drives are used for touring motorcycles and dirt bikes.
- Noisy transmission as compared to the shaft or belt drives which are completely silent.
- In case of worst-case-scenario, in which a chain breaks, it causes a hazardous situation at high speed as the chain will wrap itself around the rear sprocket and instantaneously stopping wheel. In belt drives, the belt will just fly-off upon failure. Shaft drives are quite steadfast in design.
- Cannot be used for long durations of use at a stretch as in touring motorcycles.

II. LITERATURE REVIEW

Research papers play an important role in deciding the strategy for project work completion. As stated above, there is not much literature available on analysis of a carbon fibre chain. Following are the synopses of researches by different academics regarding similar topics.

Priyanka Velhal[1] has studied the effect of tensile forces on the chain has been studied. Mainly two methods have been employed for analysis viz. FEM with practical experimentation. The scope of this paper is to study the tensile stresses, deformation, etc for the drive a regular Mild Steel chain by subjecting to FE Analysis in software and also by actual testing and comparing the results to that of Universal Testing Machine experiment.

P Sadapgaon et al[2] .have discussed the analysis of chain in wear and fatigue domain. They have also suggested certain modifications in design for reducing the effects of wear. Most of the analysis is numerical. It delves into different modes of failures of chains and shows data regarding two of the most important modes among them. This paper presents theoretical analysis on elongation and fatigue on transmission drive used in 100cc motorcycles.

Nikhil Ambole and Prof. P.R. Kale[3] investigated via reverse engineering the sprocket analysis by ANSYS software. The comparison is shown for metal and carbon fibre sprocket. The existing sprocket motorcycle is compared with the sprocket of carbon fibre material. The drawing and drafting is done using CAD software. Further FEA software is used for analysis of sprocket chain.

III. PROBLEM DEFINITION

With increasing power capacity, speeds and torque of the forthcoming motorcycles, the disadvantages of the chain drive need to be dealt with. At high speeds, failure of chains can lead to catastrophic consequences which can even prove to be fatal for the rider. Carbon fibre, with its many advantages, has quit an edge over the regular metals like mild steel, alloys, etc, and can be the long sought-after solution for the problems faced. With the apparent pros being high strength and low weight it already solves many difficulties.

The main extent of this project will be to analyse carbon fibre as a material for practical use in the final transmission chain of motorcycles. The chain design specifications of a popular motorcycle are taken and different geometric parameters are found out by the process of reverse engineering.

IV. COMPOSITE MATERIALS

Composite materials are made of a combination of two or more materials with different mechanical, chemical or physical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure, differentiating composites from mixtures and solid solutions. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

The physical properties of composite materials are generally anisotropic (independent of direction of applied force) in nature but they are typically anisotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments.

In contrast to composites, isotropic materials (for example, aluminium or steel), in standard wrought forms, typically have the same stiffness regardless of the directional orientation of the applied forces and/or moments.

Some of the important composite materials are-

- Carbon Fibres-

Carbon fibres are conductive, have an excellent combination of high modulus and high tensile strength, have a very low (slightly negative) CTE and offer good resistance to high temperatures. The exact cut-off for these categories will vary depending on the reference consulted, but in general, low modulus fibre have a tensile modulus of less than 30Msi and ultra-high modulus fibre have tensile modulus greater than 75Msi. As a point of comparison, steel has a tensile modulus of 29Msi.

- Fibreglass-

Fibreglass is, as its name implies, glass that has been spun into the form of fibres. Fibreglass is not as strong or stiff as carbon fibres, but it has characteristics that make it desirable in many applications. Fibreglass is non-conductive (i.e. an insulator) and it is generally invisible to most types of transmissions. This makes it a good choice when dealing with electrical or broadcast applications.

V. MODES OF FAILURE

The chain transmits power primarily by tensile forces acting on the linking plates. They are under continuous tension even when the motorcycle is stationary. When in motion, these plates undergo fatigue loading as there is a tighter side and slightly slack side on the either sides of the sprocket.

- **Overload**

Chain subjected to excessive one-off load which causes permanent deformation of material and leads to very short chain life.

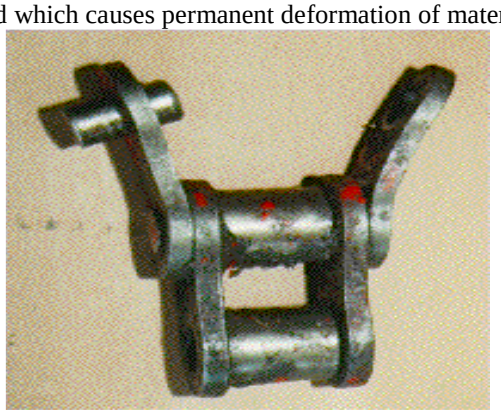

Fig. 5.1 Failure due to Overload

- **Fatigue Failure**

Fatigue failures are a result of repeated cyclic loading beyond the chain's endurance limit, or rated capacity. Extent of the overload and frequency of its occurrence are factors which determine when fatigue will occur. The overloading can be continuous or intermittent. Continuous overloading may be caused by worn teeth or pocket build-up, imposing overloads with each cycle. Impulse overloads can be from motor overload torque, dynamic overloading due to sudden stops, or impact loading on conveyors.

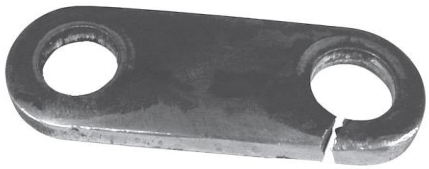

Fig 5.2 Fatigue failure of link plates

- **Wear Failure**

Load normally between pin and bush eventually wears away material such that the chain stretches beyond its usable limit. Most chains are designed to fail due to wear. Bush and pin surfaces may look smooth but at microscopic level they are jagged and the jagged parts rub against each other and produce debris.

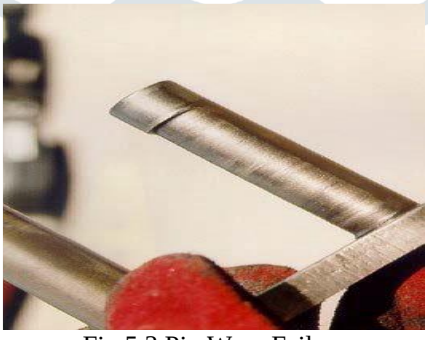

Fig 5.3 Pin Wear Failure

- **Galling**
- **Tension Failure**
- **Stress Corrosion**
- **Hydrogen Embrittlement.**

VI. FATIGUE

The number of cycles of stress or strain of a specified character (tensile, compressive, etc.) before failure of a specified nature occurs is called as the fatigue life. No. of cycles of stress that a part can endure before failure increases with decreasing stress is called as fatigue or endurance limit. In roller chains, the link plates are under continuous cyclic tensile loading which results in further fatigue failure. The fatigue strength is the maximum strength that a component can sustain for a specified number of cycles without failure.

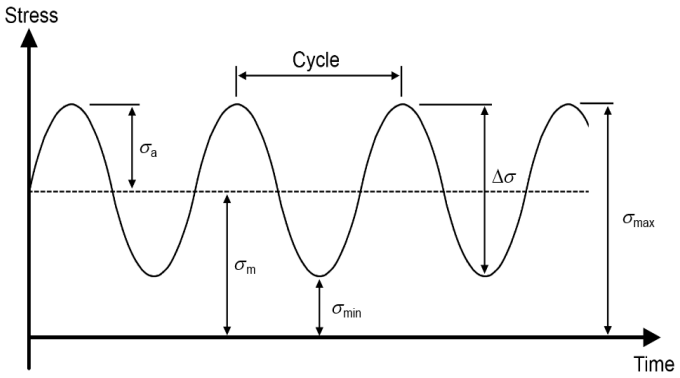

Fig 6.1 Completely Alternating Stress

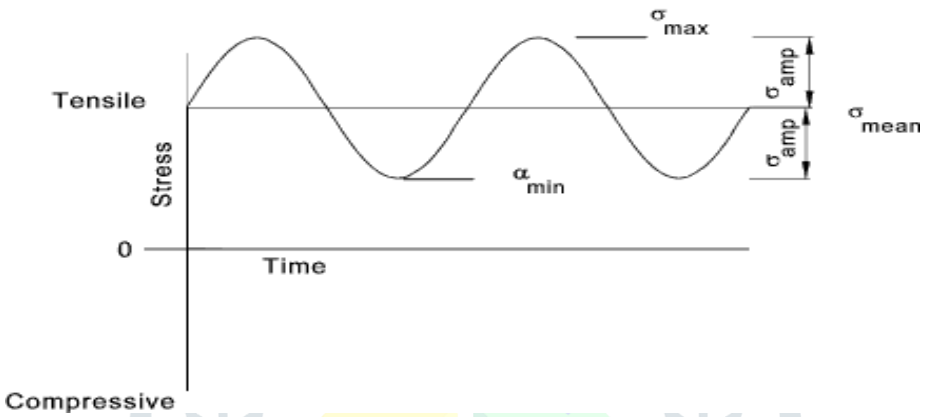

Fig 6.2 Repeated Stress

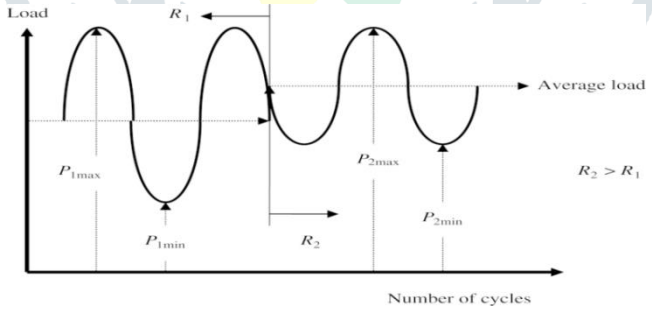

Fig 6.3 Variable Cyclic Stress

S-N CURVE

A SN-Curve (sometimes written S-N Curve) is a plot of the magnitude of an alternating stress versus the number of cycles to failure for a given material. Typically both the stress and number of cycles are displayed on logarithmic scales.

The SN-Curve functions as a "lookup table" between alternating stress level and the number of cycles to failure. Most SN-Curves generally slope downward from the upper left to the lower right. This indicates that high level amplitude cycles have fewer number of cycles to failure compared to lower level amplitude cycles.

In a fatigue test like this, the frequency at which the cycles are applied is not considered to be a factor in the number of cycles to failure. It is strictly the number of cycles, and not the rate at which the cycles are applied, that affect the SN-Curve results.

VII. DESIGN SPECIFICATIONS

Design of chain link dissertation includes design of existing chain link of Bajaj Pulsar 150cc. Dimensions of the existing chain link have been measured from market and CAD model of a chain link have been prepared in CATIA V5. The finite element analysis is carried out by using Hypermesh and ANSYS as post-processor.

CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects.

CATIA stands for **C**omputer **A**ided **T**hree dimensional **I**nteractive **A**pplication. CATIA is software developed by Dassault Systems, a France based company. It is parametric software for product development. CATIA delivers innovative technologies for maximum productivity and creativity, from the inception of concept to the final product.

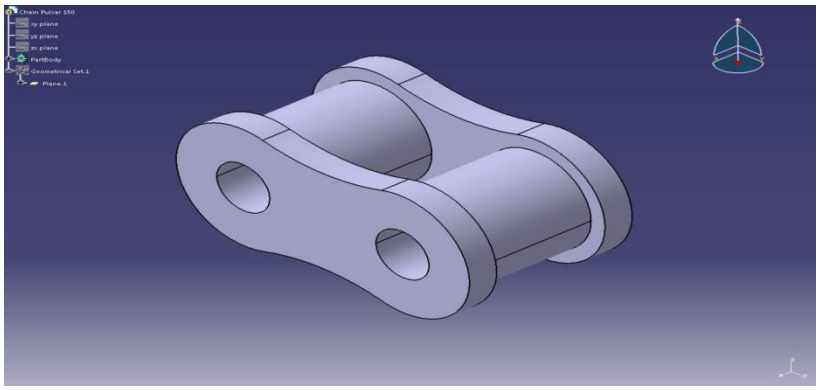

Fig 7.1 Link Plates with Rollers

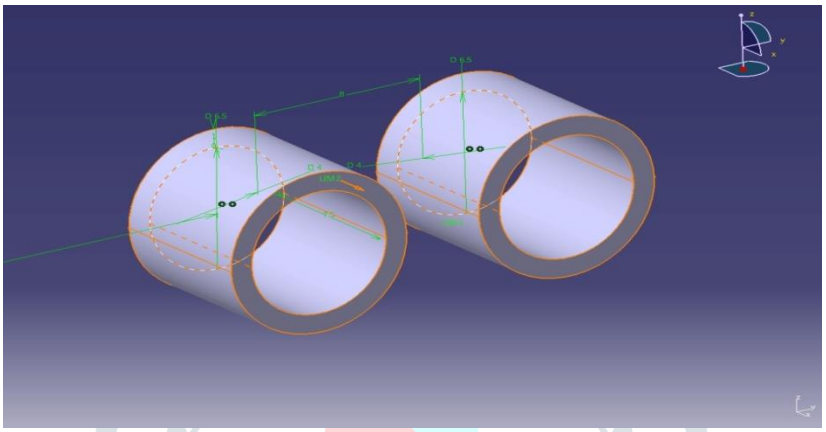

Fig 7.2 Rollers

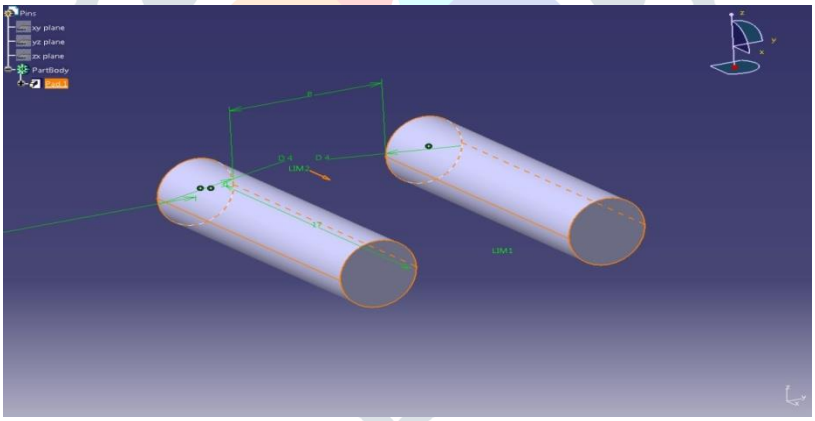

Fig 7.3 Pins

VIII. CAE ANALYSIS

The analysis for the chain is done using ANSYS software (v.16.0).The finite element analysis performed is done considering steel to be the material. This is done for putting forth a perspective before moving forward with carbon fibre as the material . Certain steps in formulating a finite element analysis of a physical problem are common to all such analyses, whether structural, heat transfer, fluid flow, or some other problem. These steps are embodied in commercial finite element software packages.
A 4.3 KN maximum force is calculated to be acting on the chain from other available information like engine power, no. of teeth and diameter of sprocket, etc. The entire fatigue analysis is done considering this as the alternating force.

Pre-processing

- The pre-processing step is, quite generally, described as defining the model and includes
- Define the geometric domain of the problem.
- Define the element type(s) to be used.
- Define the material properties of the elements.
- Define the geometric properties of the elements (length, area, and the like).
- Define the element connectivity's (mesh the model).
- Define the physical constraints (boundary conditions).
- Define the loadings.
- The pre-processing (model definition) step is critical.

Solution-:

During the solution phase, finite element software assembles the governing algebraic equations in matrix form and computes the unknown values of the primary field variable(s). The computed values are then used by back substitution to compute additional, derived variables, such as reaction forces, element stresses, and heat flow. As it is not uncommon for a finite element model to be represented by tens of thousands of equations, special solution techniques are used to reduce data storage requirements and computation time. For static, linear problems, a wave front solver, based on Gauss elimination is commonly used.

Post-processing

Analysis and evaluation of the solution results is referred to as post processing. Postprocessor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution. Examples of operations that can be accomplished include-:

- Sort element stresses in order of magnitude.
- Check equilibrium.
- Calculate factors of safety.
- Plot deformed structural shape
- Animate dynamic model behaviour.
- Produce color-coded temperature plots.

The following results for life, damage and safety factor are obtained after the analysis-

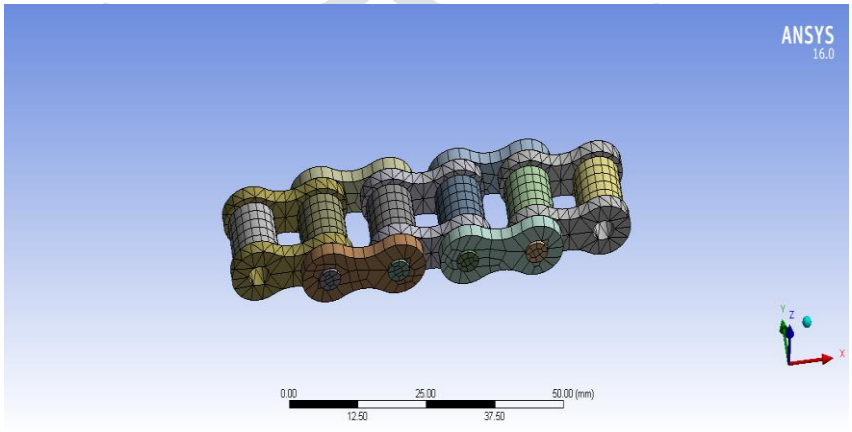

Fig 8.1 Coarse Mesh

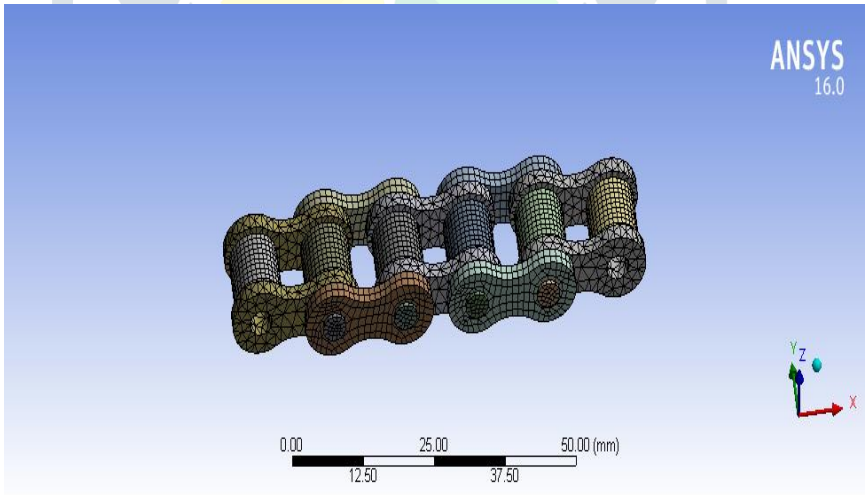

Fig 8.2 Fine Mesh

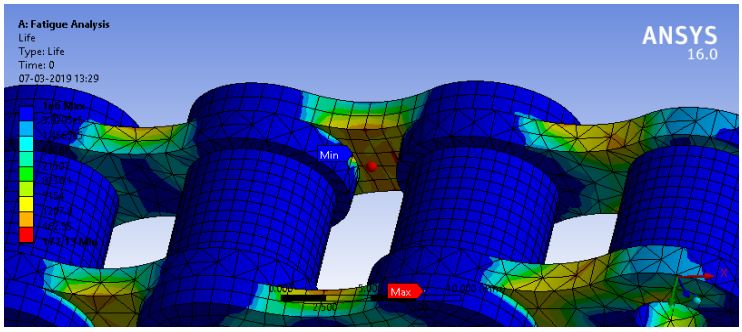

Fig 8.3 Life

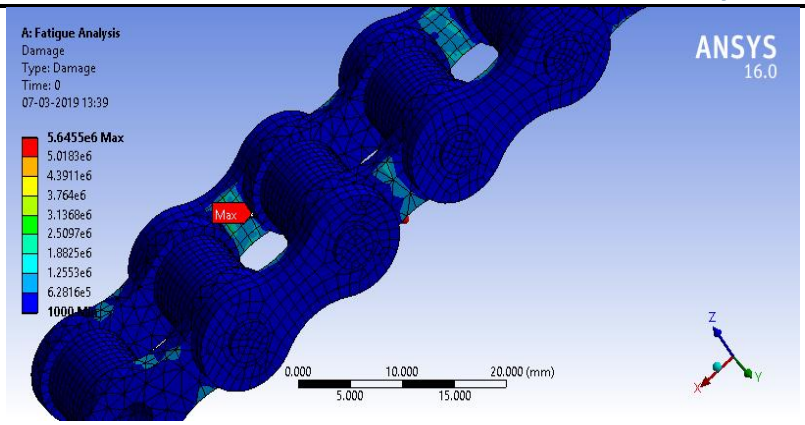

Fig 8.4 Damage

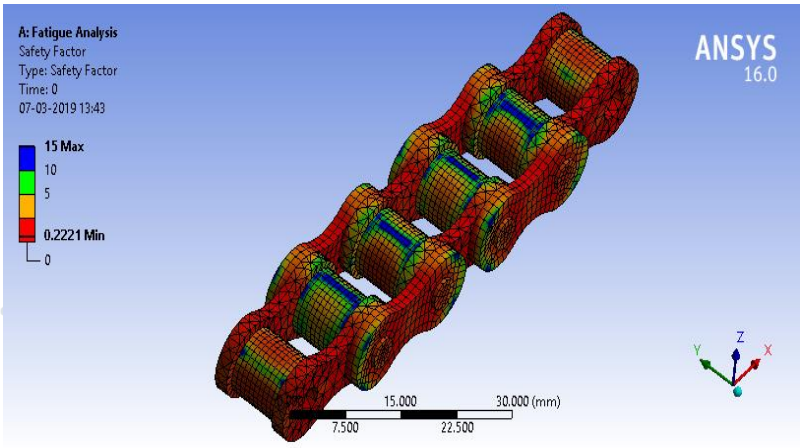

Fig 8.5 Safety Factor

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