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DESIGN AND ANALYSIS OF CHAIN DRIVE

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Abstract
The process of Chain drive Analysis is as important as its production. In today's era, it's an intelligent and profit making job to produce an optimum product. Currently, testing of chains requires machines on which a specimen is mounted and testing is done. These testing are carried out at hourly, daily or monthly rates depending upon the type of test. Some test machines are limited to a particular dimension of the product. Many changes have to be done in production as well as testing machines if it is thought to change the dimension of product, which needs a huge amount of money, time and manpower. Even if the work is limited to the testing of finished parts, there are many tests which cannot favour dimensional change.
Use of computer software can help us a lot in the field of optimization. Models for tensile Testing, Endurance Testing and Fatigue Analysis can now days are successfully analyzed on a computer. Models whose output agrees with the data from the existing test machines were tried to be made, once done the chain was optimized based on the constraints.

Index Terms – Finite element Analysis, chain drive, ANSYS, tensile load.

I. INTRODUCTION

A chain is a machine component which transmits power by means of tensile forces and is used primarily for power transmission. The function and uses of chain are similar to a belt. There are many kinds of chain. Chain can be sorted by either material of composition or by method of construction.

The chains can be sorted into four types as shown below:

1. Cast steel chain
2. Plastic chain
3. Forged chain
4. Steel chain

Classification of Chain according to their use:

1. Power transmission chain
2. Small pitch conveyor chain
3. Free flow chain
4. Large pitch conveyor chain
5. Precision conveyor chain
6. Top chain

The first chain is used for power transmission while the other five chains are used for conveyance.

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Testing of Drive Chain

Companies manufacturing chain drive usually do the testing of the drive chain in order to see whether the manufactured chain is up to their requirements. Also to survive in the competitive market the testing of chain allows the manufacturers to see what strength does their chain have and how superior or inferior their chain is as compared to the other manufacturers. A chain manufacturing company does the following test before the dispatch of the chain in order to confirm its quality:

- Tensile Test
- Fatigue Test
- Endurance Test

II. METHODOLOGY

CAD Model Generation

Solid works and ANSYS were used to create modeling and simulation. Part Modeling shows how to draft a 2D conceptual layout, create precise geometry using basic geometric entities and dimension and constrain geometry. It also shows how to build a 3D parametric part from a 2D sketch by combining basic and advanced features such as extrusions, sweeps, cuts, holes, slots, and rounds.

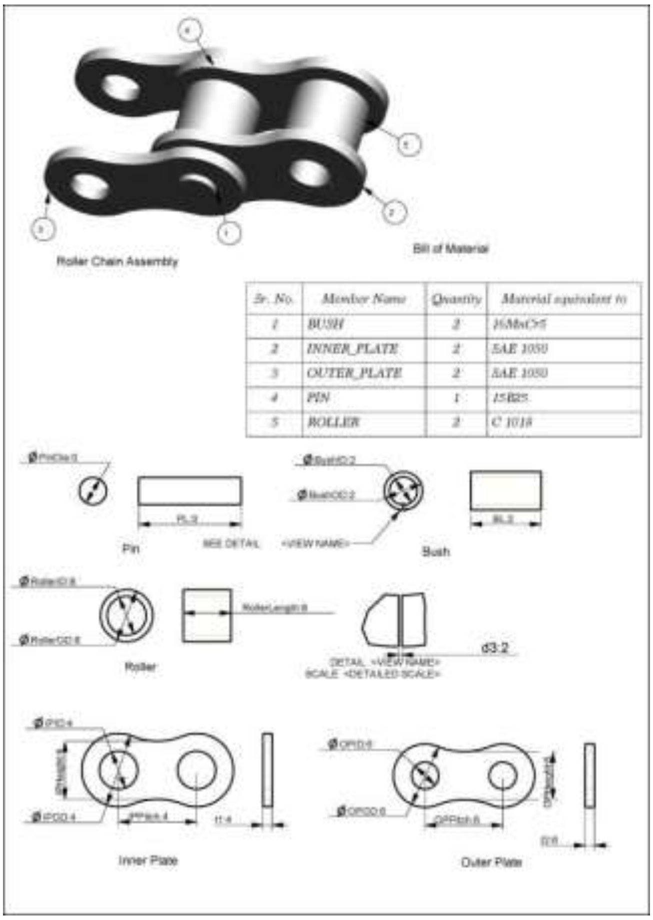

Fig.1: Geometric details of all chain elements.

Editing the Geometry for applying boundary conditions

The geometry file modified so that required contact regions can to be created. Trim the faces so as to make a face which is of our interest.

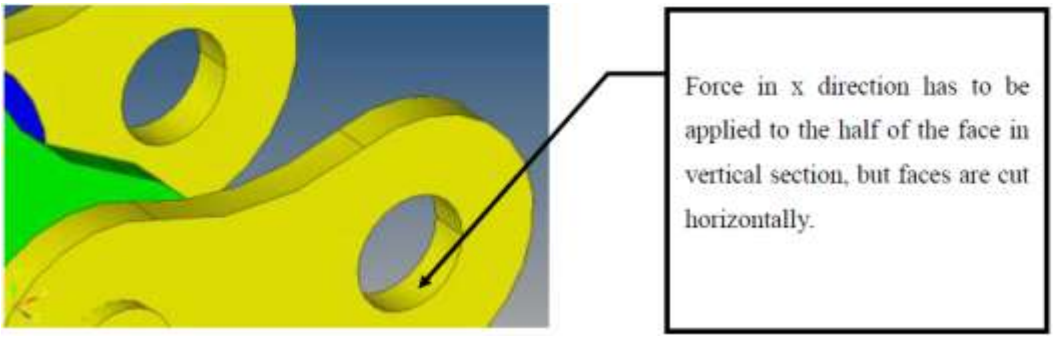

Fig.2: Assembly imported for analysis purpose.

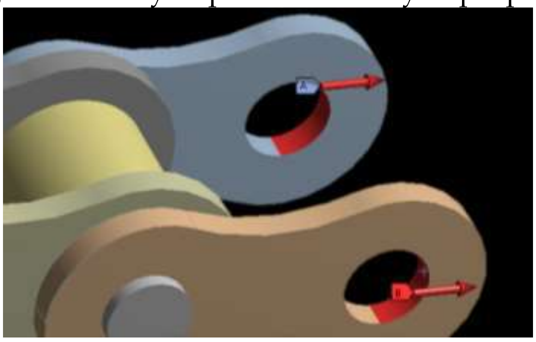

Fig.3: Assembly after cutting faces and applying forces

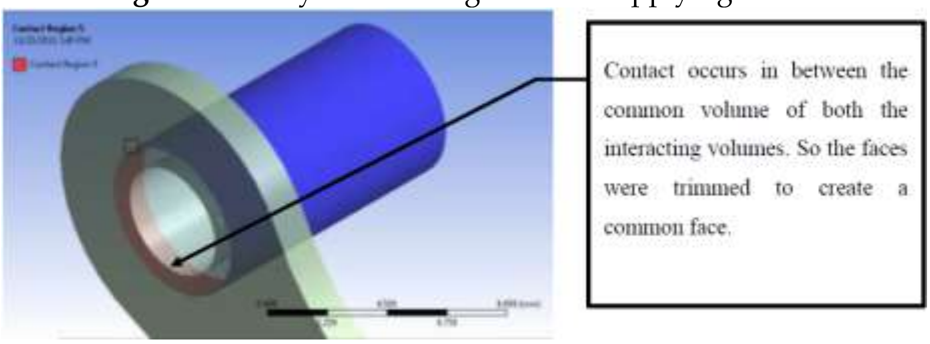

Fig.4: Default Contact Region.

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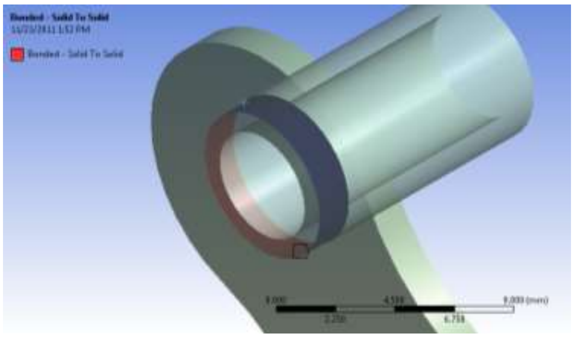

Fig.5: Contact Region after Trimming Faces.

Many such contact faces were trimmed as shown in Figure 4 and Figure 5 and the final model is shown Figure 6.

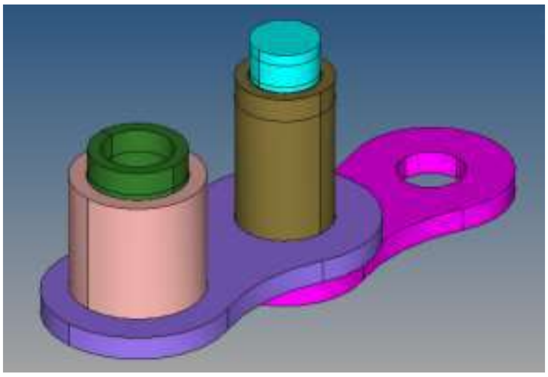

Fig.6: Final Model of Assembly showing Faces Cut.

Table 1: Tensile Strength of different Components.

Component Name	Outer Plate	Inner Plate	Roller
Tensile Strength (MPa)	1339.04	1385	631.02

Table 2: Material Properties

Component	Hardness	Tensile Strength(MPa)	Poisson's Ratio	Young's Modulus(MPa)
Inner Plate	43 (HRc)	1337	0.29	2.00E+05
Outer Plate	43 (HRc)	1337	0.29	2.00E+05
Bush	430 (Hv)	1366	0.29	2.05E+05
Roller	410 (Hv)	1303	0.29	2.00E+05
Pin	455 (Hv)	1444	0.29	2.05E+05

III. FINITE ELEMENT ANALYSIS

Optimum Model Based on Pilot Study

Optimum model consisted 24 bodies having bonded contact in between the inner plate and bush, outer plate and pin; frictional contact in between the pin and bush, bush and roller.

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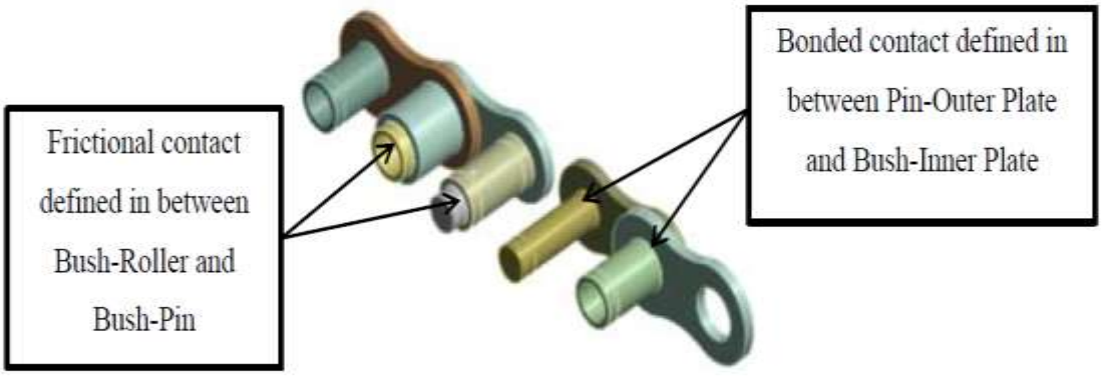

Fig.7: Contacts details of the optimal model.

Minimum element size of 0.5 mm was used during the mesh and it was taken into account that there are least 4 elements along the width of each plate. The model generated 449218 nodes and 91242 elements.

Boundary Condition

Inner plate being the only body which was being gripped on all the four corners in the gripper, was held fixed on the four corners as shown in Figure 8 and a gradually increasing load was applied on the other end of the inner plates as shown in Figure 9. Direct load cannot be applied to the model as it had contact non-linearties in it. Hence to fill the initial gap in between the pin and the bush, gravity was applied in the direction of the force so that the bodies can come in contact with each other. After the application of gravity a load of few Newton's was applied so that the frictional contact would become stiff enough and prevent the penetration of the contacting bodies. The load was then applied with a proper amount and kept gradually increasing till 1900 kgf. Table 1 shows the value of load and the time at which the respective step gets complete.

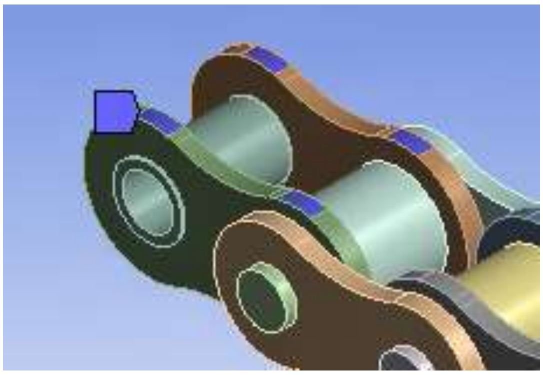

Fig.8: Fixed end of the Chain

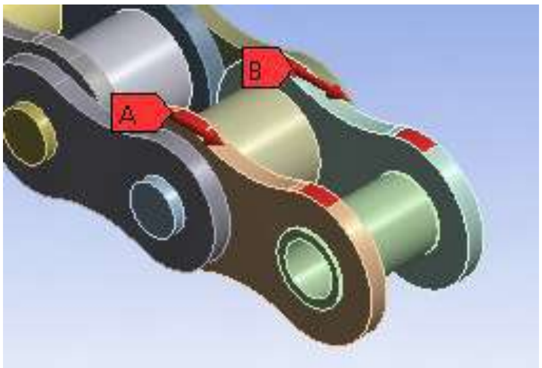

Fig.9: Loading end of the Chain

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Table 3: Load Step Details (Tensile Test)

Time (s)	**Force (N)**	**Gravity (mm/s2)**
0	0	0
10	0	9806.6
20	4	9806.6
150	2000	9806.6
250	4500	9806.6
350	6000	9806.6
450	8000	9806.6
550	9319.5	9806.6

The force of 9319.5 N was applied on each inner plate which totally made a sum of 18639 N which was applied in two parts namely 'A' and 'B' as shown in Figure 9

Input Data:-

Material data required for the analysis was given from Table 2 which had Young's modulus, Poisson's ratio and tensile strength of respective component. To be on a safe side, the maximum stress was not allowed to be greater than 1303 MPa, which is the minimum stress at which a component breaks. Taking the minimum stress at which a component breaks as the maximum allowable stress on the whole chain, the load on the chain was increased and finite element model was checked. To exactly define the elastic and plastic data, the stress v/s strain curve for each component was entered using Multilinear Isotropic Hardening option in the engineering data component.

Results of Optimal Model

Finite element model showed that the chain would break at a load of 1834 kgf as that actual breakage load of 1850 kgf.

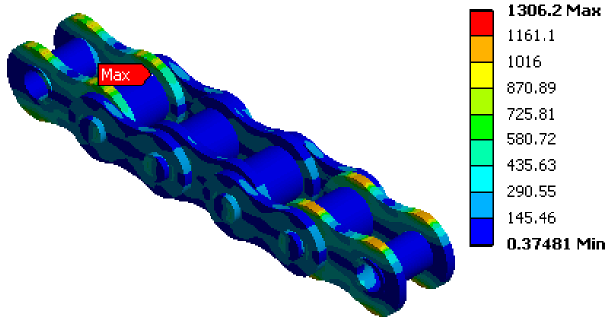


Fig.10: Stress variation over the chain for the optimal model during tensile test

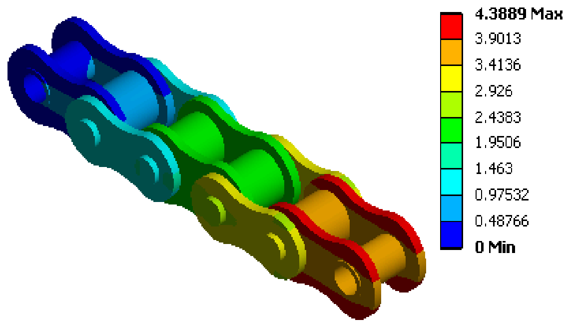


Fig.11: Deformation of the chain (mm) for the optimal model during tensile test

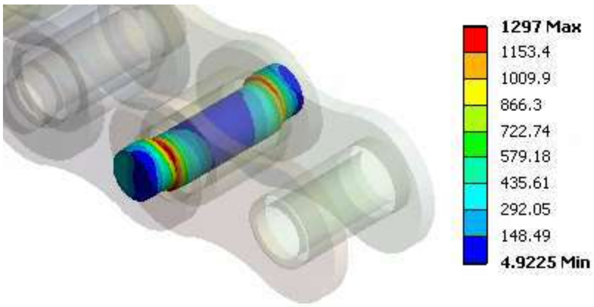


Fig.12: Stress variation over the most stressed member, i.e pin.

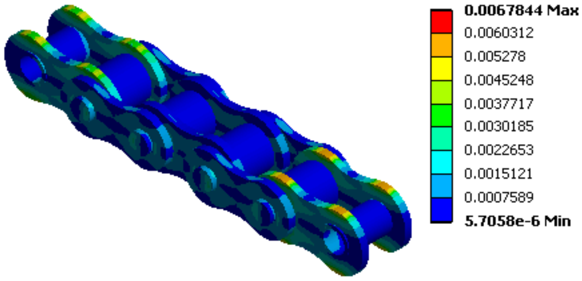


Fig.13: Strain variation over the chain for the optimal model during tensile test.

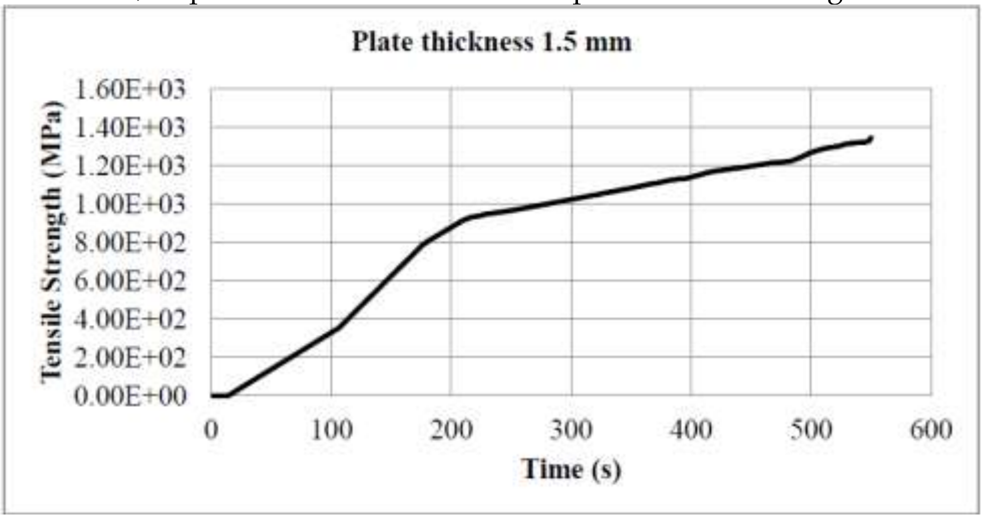


Fig.14: Stress history for the optimal model during tensile test

Stress of 1306.2 MPa came at time 525.46 seconds. The curve in the Figure 14 shows the stress levels at the different time interval in the solution. At the end of first step when gravity was applied the stress value was found to be 2.76E-01 MPa. The stress value at the end of each step is shown in Figure 15 along with the load applied during the respective step.

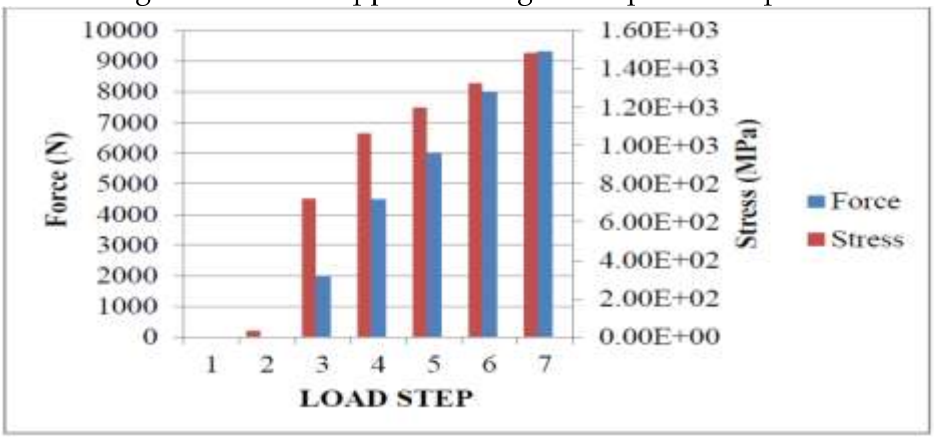


Fig.15: Stress (MPa) and Force (N) at the end of each load step for the optimal model during tensile test

Model optimization for Chain Weight Reduction

A model which can easily predict the tensile strength of the chain drive was successfully made based on which it was optimized for the given dimensional tolerance. Initially, the plate thickness whose value was 1.5 mm was varied in a given range of 1.5 mm to 1.2 mm. Tensile strength at each change was studied for reduction of 0.1 mm in the present value of 1.5 mm.

The distance between the inner plates and outer plates was kept constant. This constant distance got varied because of change in thickness. In order to keep both the plates at the set distance, pin and bush length was reduced. For every 0.1 mm reduction in the thickness, the pin length got reduced by four times and the bush length by two times.

Thickness of plates reduced to 1.4 mm

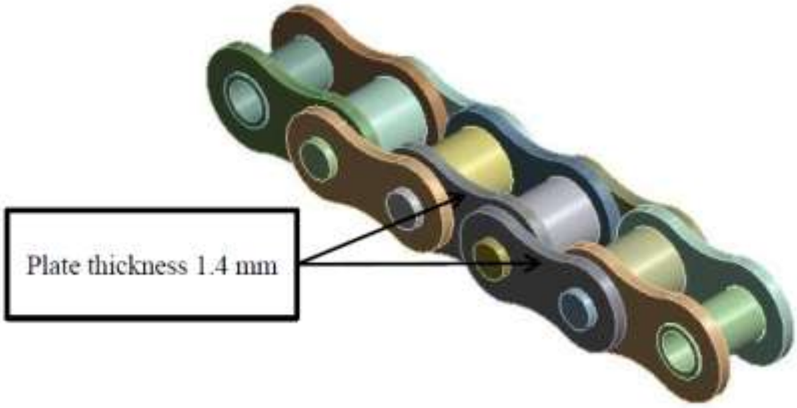
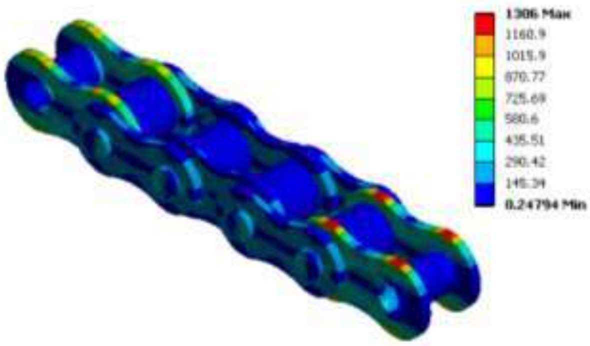


Fig.16: Model with 1.4 mm thick plates



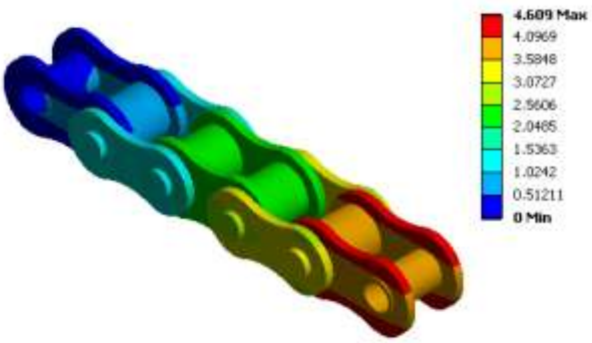
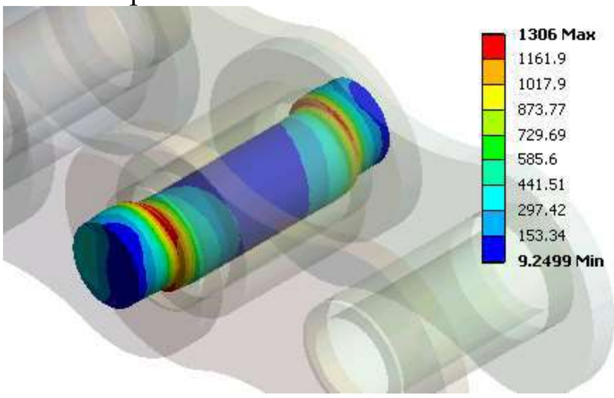


Fig.17: Stress variation over the

Fig.18: Deformation of the chain for plate

chain for plate thickness 1.4 mm

thickness 1.4 mm



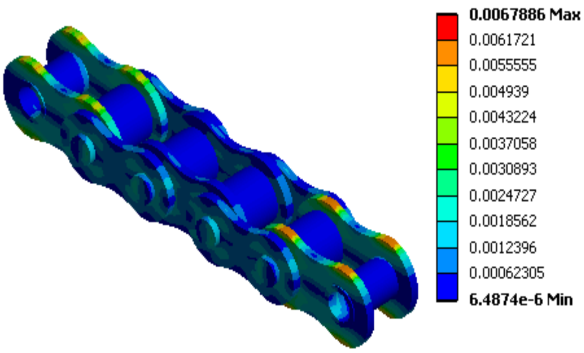


Fig.19: Stress variation over the most stressed member for plate thickness 1.4 mm

Fig.20: Strain variation over the chain for plate thickness 1.4 mm

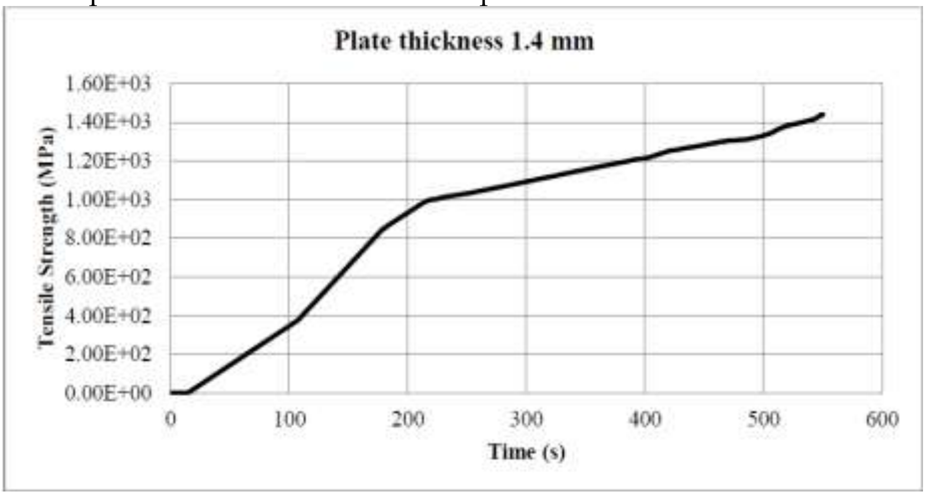


Fig.21: Stress history when the plate thickness is 1.4 mm for tensile test.

Stress of 1306 MPa came at time 476.76 seconds. The curve in the Figure 21 shows the stress levels at the different time interval in the solution. At the end of first step when gravity was applied the stress value was found to be 2.88E-01 MPa. The stress value at the end of each step is shown in Figure 22 along with the load applied during the respective step.

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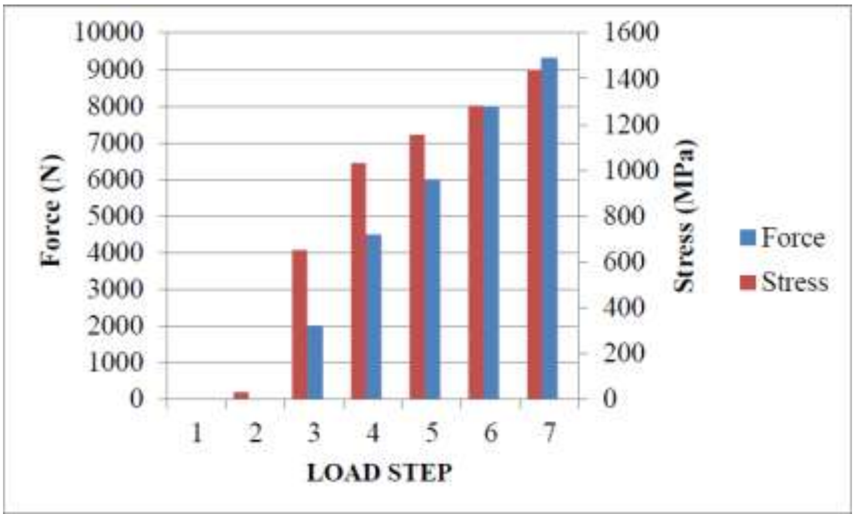

Fig.22: Stress (MPa) and Force (N) at the end of each load step when the plate thickness is 1.4 mm for tensile test.

IV. RESULTS

Thickness of plates reduced to 1.2 mm with proposed design

The chain manufacturer had also proposed a new design with a plate thickness of 1.2 mm. All the chain components were made with the new dimensions and the test was performed.

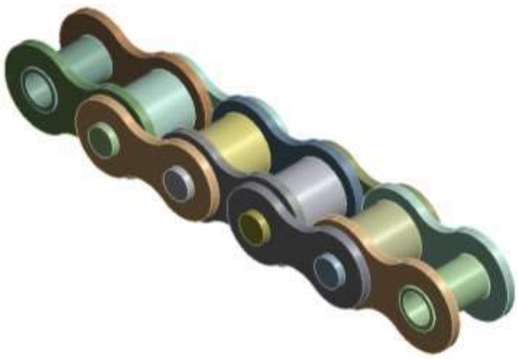

Fig.23: Model with 1.2 mm thick plates and proposed design.

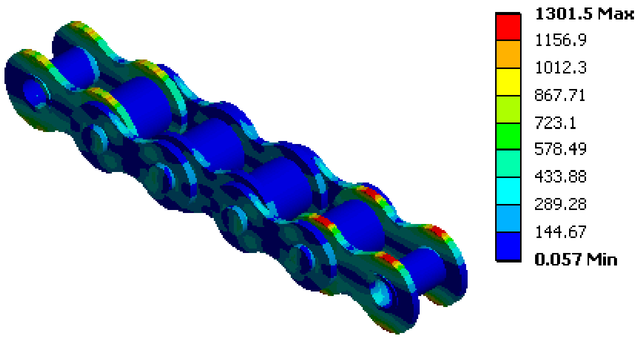

Fig.24: Stress variation over the chain for plate thickness 1.2 mm with proposed design

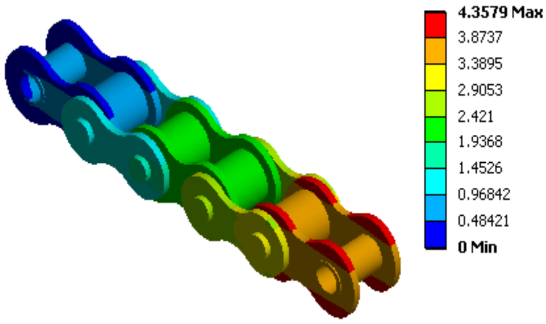

Fig.25: Deformation of the chain for plate thickness 1.2 mm with proposed design

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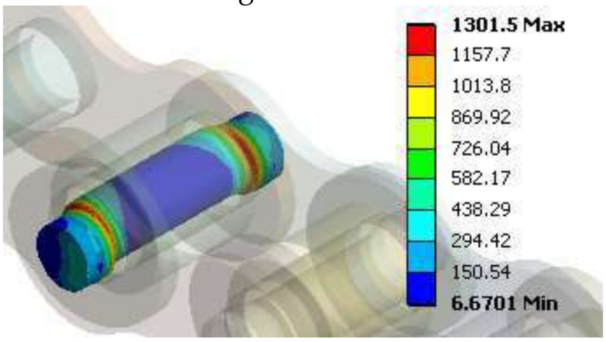
The model as shown in Figure 23 is solved for given boundary conditions. Tensile strength if found to be 1371 kgf. The stress variation over the entire model is shown in Figure 24.



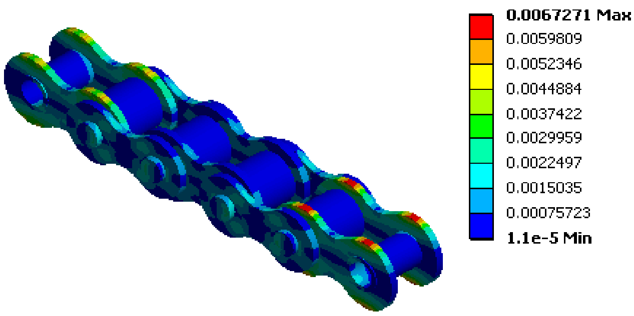


Fig.25: Stress variation over the most stressed member for plate thickness 1.2 mm

Fig.26: Strain variation over the chain for. plate thickness is 1.2 mm with proposed design

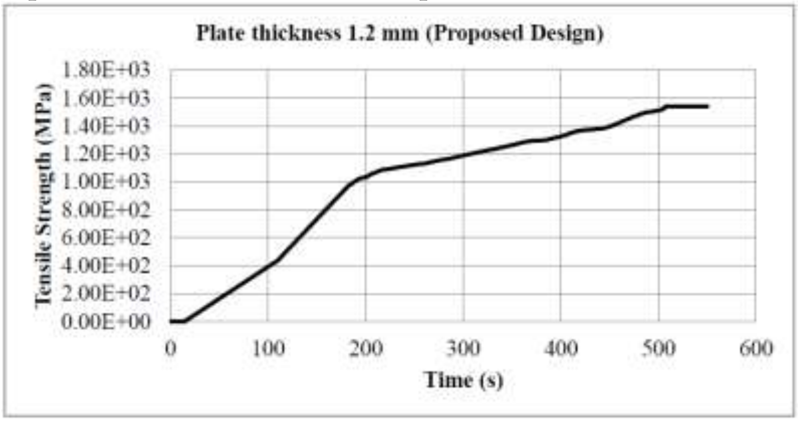


Fig.27: Stress history when the plate thickness is 1.2 mm with proposed design for tensile test

Stress of 1301.5 MPa came at time 386.2375 seconds. The curve in the Figure 27 shows the stress levels at the different time interval in the solution. At the end of first step when gravity was applied the stress value was found to be 0.35891 MPa. The stress value at the end of each step is shown in Figure 29 along with the load applied during the respective step.

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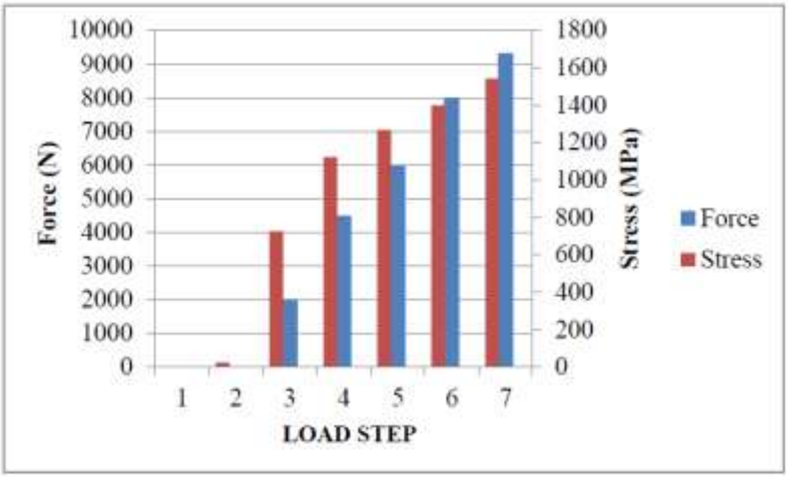

Fig.29: Stress (MPa) and Force (N) at the end of each load step when the plate thickness is 1.2 mm with proposed design for tensile test

V. CONCLUSION

Based on present work of developing model for tensile test, the following conclusions are drawn:

1. Based on the proposed dimensions, a new model has been proposed with high tensile strength.
2. A graphical visualization of the stresses developed on the body and chain elongation is made and the most stressed body is predicted
3. Tensile test can be done easily and any load change can be easily incorporated in the test as compared to the actual testing which required a high amount of lead time, changes in dies, jigs and fixtures. Hence, geometry and material change for all the models can be successfully evaluated without manufacturing the chain.
4. Use of parametric model removed the hectic task of creating new model for every change in a particular dimension. Any dimensional change can be easily included within no time and use of relations in between two bodies gave automatic regeneration of second body whenever the dimension of first body is changed.

Scope of future work

Use of finite element method has helped to develop successfully the models which can predict the tensile strength. There are a lot of new elements being developed and a number of new methods which leave the future scope unbounded. Scope of future work is being discussed below.

1. For tensile testing, the fracture can also be graphically shown with the help of fracture data being specified along with the material data.
2. Model Order reduction software's are available which can reduce the model to a good extent and reduce the computational resources need and time required for the simulation.

FEA packages have capability to calculate the damage matrix, rain flow matrix, hysteresis and fatigue sensitivity based on the proper fatigue material data.

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