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# Stress Analysis and Shape Optimization of Stacker Chain (pitch 75 mm)

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## ABSTRACT

**Stacker chain conveyor is suitable for stacking bags at various heights from floor. Bag Stacker Conveyor is most useful for stacking 50 to 100 kg sugar bags in sugar industries. It reduces the time and manpower considerably and become an indispensable part of storing activities. Different types of pitches are maintained in chains as per stacker construction. These bag stacker chains are of robust construction and available in ready stock. This paper is focus on shape optimization of inner link plate of stacker chain by finite element analysis. Without compromising in breaking load and material shape optimization has been done to reduce weight of stacker chain.**

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## I. INTRODUCTION

Economy of state is dominated by agricultural as well as industrial sector. Sugar factories play important role in economy of state. About 60 percent processes in these factories are based on roller chain conveyers. Apart from that, other industries also use these chains frequently for process atomization. Sugar bag handling is a critical process in sugar factory. It should be safety and speedy process. Bag Stackers can be used in all sugar factories to stack bags. This can be also used for loading and unloading. The advantage of using bag stacker reduces manpower and time and for quick process. Bag Stacker Conveyor is most useful for stacking 50 to 100 kg sugar bags. With a top height of 18 feet it reduces the time and manpower considerably and become an indispensable part of storing activities.

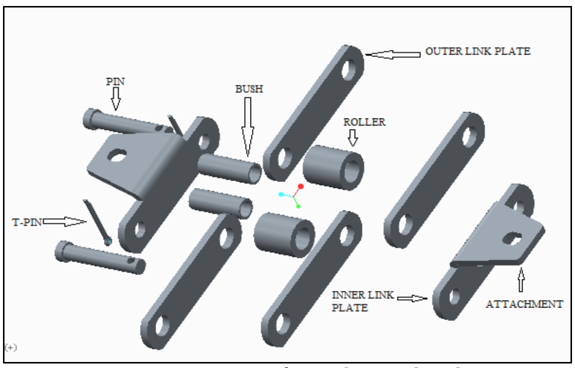


Fig. 1: Basic structure of sugar bag stacker chain.

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. Normally medium alloy steel i.e. as per Indian Standard C45, 55C8 or as per British Standard EN8, EN9 has been used in normalized condition and after manufacturing of link it has been heat treated up to 35 to 40 HRC in order to get tensile strength up to 70 to 80 kg mm².

Some innovations were devoted on improving chain components and articulation of the chain. Hollingworth and Hills [2] worked on forces in a heavy-duty drive chain during articulation. A rigid-body analysis is presented of the forces which occur in chain bearing in an articulation. The analysis differentiates between the two types of chain bearing open end leading or open end trailing and the results show that the force characteristics in each are significantly different. Experimental verification of the chain link tension is good. Miyazawa and Satoh [3] developed a method of manufacturing a link plate for a roller chain which results in minimization of the link plate deformation, a bending failure generated by the interference between a warped link plate and the adjacent link plate. Moster and Ledvina [4] developed a roller chain assembly by adding material to the location on the link plate face where fatigue failure is most likely to occur. The material increases the strength of the link plate, allowing for the use of inner links having larger bushings.

Apart from patents on chains and conveyer, few researchers have published theoretical and experimental works in this area. Initial research on chain [5, 6] was focused on kinematics and dynamics study of chain and sprocket combination. An analysis to determine the effects of pitch difference, friction, and centrifugal forces on the load distribution of a roller chain was carried out by Naji and Marshek [7]. Friction was shown to cause higher tooth load on driven sprocket than that of a driver sprocket. This research area was further extended for dynamic analysis of oscillation in chain drive and computerized roller chain drive selection [8-9].

Very few researchers worked on stress analysis of roller chains. Ozes and Demirsoy [10] examined the effects of various loading condition on the stress of a pin-loaded woven-glass fiber rain forced epoxy laminated conveying chain component. A numerical & experimental study was carried out to determine the stress distribution of composite conveying chain components used to convey loads. The commercial finite element package ANSYS was used to perform the numerical analysis using a three dimensional eight nodded layered structural solid elements. Chain tensile forces were loaded through pins and chosen as 250, 500, 750, 1000 and 1250 N for the two conditions of chain components. Experimental and numerical studies were compared and discussed for two conditions and five different tensile forces. A good agreement between experimental results and numerical result predictions was obtained. [11] Design team worked on the ANSY size 60 roller chain is sufficiently sized to safety operate when connected to the 10 hp engine used by the mini Baja. This size roller chain is typically used in motorcycles with engines capable of producing 50 to 70hp. The Finite Element study conducted here estimations of the design team. Noguchi et al [12] proposed some methods of weight saving for roller chains. These methods are based on Finite Element Method analysis of the stress and deformation in the link plate of roller chain and also approaches for reducing stresses and weight saving in the link plate of the roller chain. Stress are 3% higher in the proposed design, but the weight is reduced by 10%. Tensile tests are performed on link plates made of resin, and the effectiveness of the proposed model is confirmed. Korey et al [13] two dimensional geometrical model of the chain link is formed and stress analysis is performed using both boundary element and finite element methods. The researchers are proved Boundary Element Method is more appropriate for the chain link application than the finite element method.

After the analysis work very few researchers were developed on optimization of roller chain. Burgess and Lodge [14] investigate the optimization of the chain drive system on sports motorcycles. The transmission efficiency of the chain drive has a very significant effect on the performance of sports motorcycle. Sergeev and Moskalev [15] have worked in investigating the coupling in a chain transmission. This entails investigation of the coupling geometry and parametric optimization of the sprocket. Dasari and Ramesh [16] investigate the analysis of a complex shape chain plate using transmission by using photoelastic technique. Here researchers explained how transmission photoelastic technique is used to estimate the stress distribution and its concentration zones in a complex chain late when it isolated.

From the various studies, it can be noted that, even though several patents are filed on roller chains, most of the patents based on improvement of efficiency and performance. Hardly here are very few patents available which focuses on improving life of the chain and minimization of its failure. It can also be noted that the analytical work in the literature is focused on load estimation. Very few researchers have explored the fatigue life estimation and stress analysis for the chain assembly. However, literature on uncertainty analysis due to improper shape of roller chain is present. The failure case studies also indicate that the birth of some failure modes is given at the time of designing stage itself.

## II. FINITE ELEMENT ANALYSIS OF SUGAR BAG STACKER CHAIN

The finite element analysis (FEA) is a computational technique used to obtain approximate solution of boundary value problems in engineering. Simply stated, a boundary value problem is mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. The static structural analysis of EN8 material stacker chain is done by finite element analysis using ANSYS 16 software. The properties of the material used are given in the table below. The analysis is done on a 3D model.

| Material Property | Notation | EN8 | Unit |
|---|---|---|---|
| Modulus of Elasticity | E | $2.06 \times 10^5$ | MPa |
| Poisson Ratio | v | 0.3 | - |
| Density | ρ | 7800 | $Kg/m^3$ |

There are certain common steps in formulating a finite element analysis of a physical problem, whether structural, fluid flow, heat transfer, vibration and some other problem. These steps are usually embodied in commercial finite element software packages. There are three main steps, namely: preprocessing, solution and post processing. The preprocessing (model definition) step is critical. This step includes; define the geometric domain of the problem, the element types to be used, the material properties of the elements, the geometric properties of the elements (length, area and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings. The next step is solution, in this step the governing algebraic equations in matrix form and computes the unknown value of the primary field variables is assembled. Actually the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software. The final step is post processing, the analysis and evaluation of the result is conducted in this step. The chain link to be optimized is shown below.

 

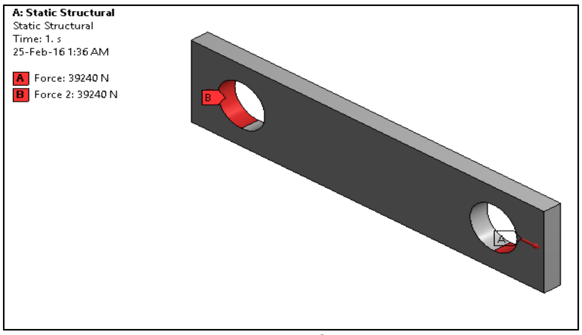


Fig.2: Link 1

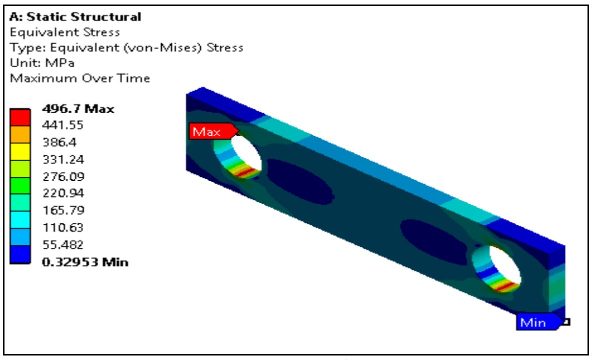


Fig.3: Von Mises Stress plot for chain link 1

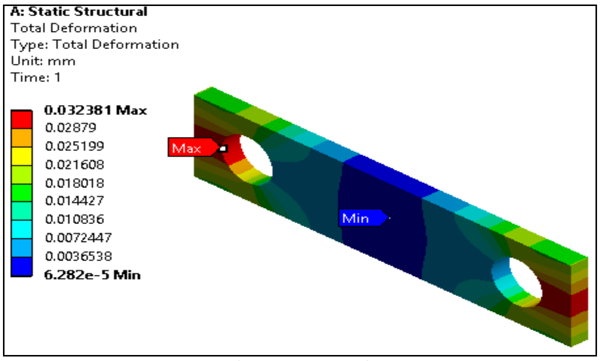


Fig.4: Total deformation plot for chain link 1

From the Von Mises Stress Plot, it is visible that there is scope for removing material from the chain where the stress level is very low. Now start the optimum material reduction and the changes in the stress plot and deformation plot will be analyzed. For this, several models are made and analyzed for the same load. As per the results obtained above, the stress of around 385 Mpa and deformation of about 0.032 to 0.035 mm will be acceptable. The different shapes of chain link 1 are shown below with the Von Mises Stress and Total Deformation plots.

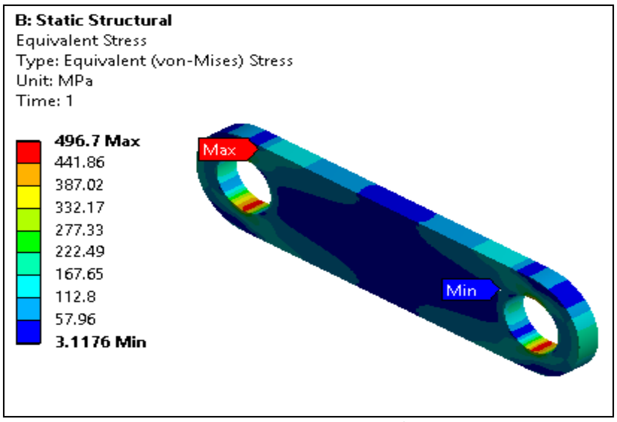


Fig.5: Von Mises Stress Plot of Shape 1

The maximum stress is 496.7 MPa at the minimum cross section of the chain link 1.

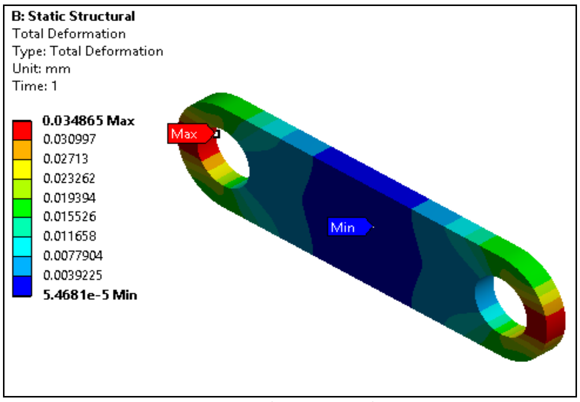


Fig.6: Total Deformation of shape 1

The maximum deformation of the shape 1 chain link 1 is 0.034 mm.

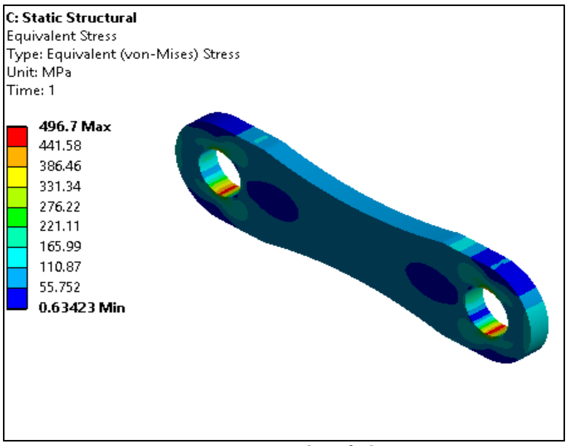


Fig.7: Von Mises plot of Shape 2

The maximum stress is 496.7 Mpa at the minimum cross section of the chain link 1.

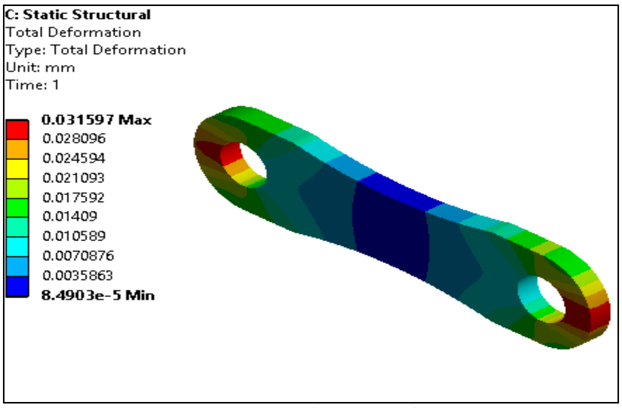


Fig.8: Total Deformation of shape 2

The maximum deformation of the shape 3 of chain link 1 is 0.032 mm. After removing the material from shape 2, the optimum shape will be achieved. It will look like below.

 

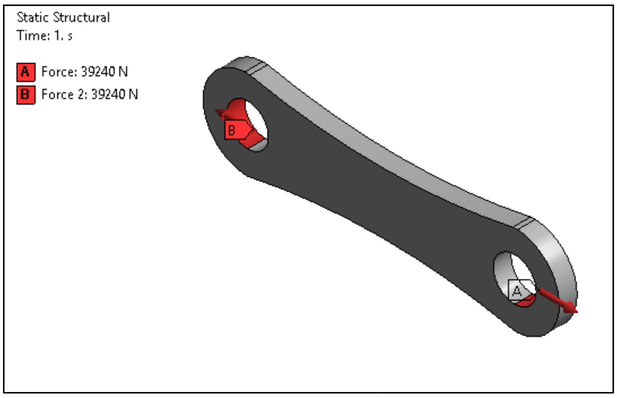

Fig.9: Shape 3 of link 1

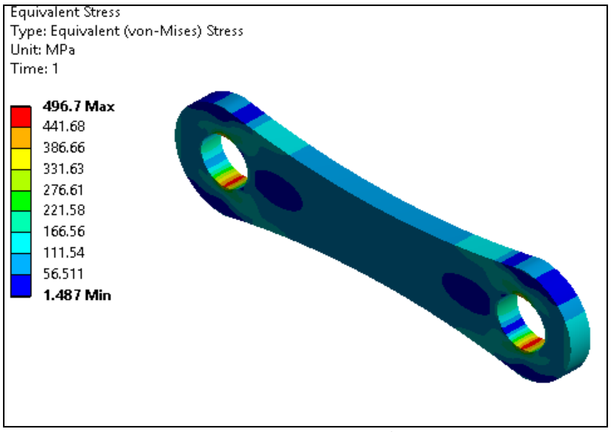

Fig.10: Von mises plot for shape 3

The maximum stress is 496.7 Mpa at the minimum cross section of the chain link 1.

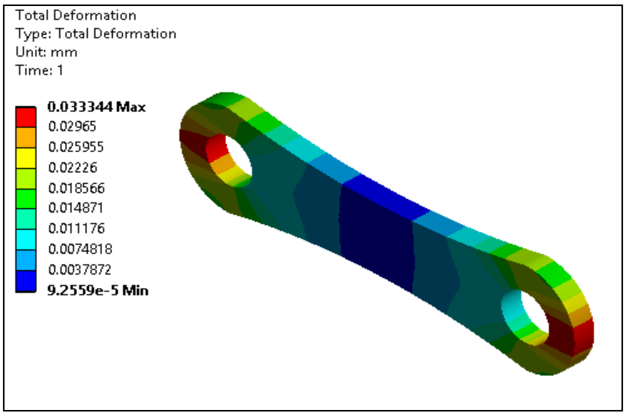

Fig.11: Total deformation of shape 3

The maximum deformation of the shape 3 of chain link 1 is 0.033 mm.
The stress and total deformation plots denote that the shape 3 of the link 1 of chain will bear the required load and sustain the stress developed under the given conditions. Thus the optimum shape of the chain has been achieved successfully with considerable amount of material removal from the chain link 1.

## III. CONCLUSION

Based on the FEA results, it is observed that the weight of inner link plate of sugar bag stacker chain has been reduced significantly. It must be noted that in a typical industrial application, thousands of such links will be needed. The weight saving thus achieved will have a significant impact on cost of the chain, and more importantly with a lighter chain, the cost savings during operation will also be significant

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