FINITE ELEMENT ANALYSIS OF FORGED CHAIN AND WEIGHT OPTIMIZATION.

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Abstract: A forged chain is commonly used in industrial conveyors and processing equipment, in construction and agricultural equipment, an oil well drilling rigs, and in large stationary load transmission. lot of work has already been done in increasing life of the chain, in this work the focus has been narrowed down to reducing weight, reducing power consumption within the forged chain. Most dimensions in the industry are parametrically defined, however, one dimension, the thickness of the web is in between interconnecting holes is left to manufacturer convenience. In this work, we assess the impact of this web on the stress in the system and see if material saving and consequently efficiency increment is possible.

***Index Terms* -** Forged chain**,** Finally Finite Element Analysis, Weight optimization.

I. INTRODUCTION

Economy of Maharashtra state is dominated by agricultural as well as industrial sector. Sugar factories play an important role in economy of Maharashtra state. About 60 percent processes in these factories are based on chain conveyors. In this study a shape optimization process is used for the design of forged chain link assembly for minimization of failure modes. This process has various design variables, such as wall thickness of link web, breaking area of link. Strength of the attachment depends on limit, fit, tolerances and weight of the attachment. While deciding the shape optimization of forged 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 55C8 or as per British Standard 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.

II. LITERATURE REVIEW

Suhas M. Shinde et. al.[1] In that paper study existing conveyor system and optimize the critical parts like roller, shafts, C-channels for chassis and support, to minimize the overall weight of assembly and material saving. In that Paper Author has worked on redesign. Existing gravity roller conveyor system has designed and also there critical parts (Roller, Shaft, Bearing and Frame), to minimize the overall weight of the assembly and to save considerable amount of material.

Jagtap et. al.[2] This paper is about the behavior of chain strip under tensile loading. In turn it will help in reducing down time and maintenance cost related to chain assembly in various industries. In this paper we study the analytical, experimental and numerical behavior of strip under tensile loading.

V. Velkova et. al.[3] This paper presents a novel process chain for fabrication of replication masters for serial manufacture. The proposed process chain is validated for serial fabrication of (large area) organic electronic devices on flexible substrates. The advantages and limitations of the component technologies in the proposed manufacturing route are discussed and their process chain for producing both 2.5D and 3D nanostructure and micro-structures are analyzed.

Nur Ismalina et. al.[4] This paper study to investigate the causes of failure of chain system through characterization on the failure component. The failures that occur are relate to welding because this dipping latex industry use customized chain that have to be welded at joining with outer chain links. The analysis revealed that the weld defect such as crater leads the crack propagation and added with cyclic loading that cause the fatigue failure. The fatigue failure occurs due to this inherited crack at the outer circumference of the weld within chain attachment and outer chain link plate. This type of defect also can be categories as designing-in defect. Fatigue crack propagation was evident by progressive beach marks and the scanning electron microscopy (SEM) analysis revealed the types of microstructure that resulting at heat affected zone (HAZ). Hardness testing by using Rockwell Tester found the different hardness profile at three areas that are weld metal, base metal and heat affected zone. The maximum hardness values were found at heat affected zone and weld metal. Finite element method (FEM) that is Ansys Workbench was used to review the different size of outer link plate thickness that affected to the stress distribution. It was found that stress can be minimized with increasing the plate thickness.

S. R. Kale et. al.[5] In resent work he had studied the different failures of roller conveyor chain links under different loading conditions using Mild Steel. In chain conveyor system motor capacity of conveyor depends on the weight of chain. It was determined that maximum amount of weight of chain conveyor is covered by outer link and inner link. He concentrated on both link and weight reduction of link by using composite material (Glass Fiber & Carbon Fiber) to reduce the power requirement of conveyor.

Ravishankar Rai[6] The basic aim of this review paper has been conducted on failure analysis check the shackles chain link strength and stress analysis respect of external load and environment condition with help of Finite element analysis (F.E.A) the shackles chain link strength is very useful for lifting mechanism, it is failure due to double shearing, crossing, wear etc.
The main object of this work calculate and compare the privies results with Finite element analysis (F.E.A) result and reduce the stress by design manipulation of mechanical shackles chain link component the Finite Element Method (FEM) and Finite element analysis (FEA) is best mathematical numerical solution for find the strength and stress of mechanical components. This paper presents that failure of chain link and stress analysis is widely done by Finite Element Method (FEA & FEM) and design

optimization tool. The chain link are consider different loading condition, different behavior of failure and design parameter. FEA apply in mechanical element and link, we find in which the parameter are effect to its failure. The FEA-based simulated model gives a reasonable approximation of simulated parameters and generates the mesh FEA model, and gives the result respect number of node and element the mesh FEA model.

III. Forged Chain

Forged chain is more suitable to long term continuous running and conveying the sugar can with limited torque fluctuation but as we know Forged chain had continuously gone through repeated heavy loads. The key chain assembly failure of different parts of chain along with failed component of the chain and their causes of failures are explained below.

Fig. 3.1 Chain Link

Fig. 3.2 Pin

Fig. 3.3 Bushing

Fig. 3.3 Chain Assembly

- **Plate/Link**
  The plate shown in fig. 3.1 is the component that bears the tension placed on the chain. Usually this is a repeated loading, sometimes accompanied by shock. Therefore, the plate must have not only great static tensile strength, but also must hold up to the dynamic forces of load and shock. Furthermore, the plate must meet environmental resistance requirements (For example: - corrosion, abrasion, etc.).

- **Pin**
  The pin shown in fig. 3.2 is subject to shearing and bending forces transmitted by the plate. At the same time, it forms a load-bearing part, together with the bushing, when the chain flexes during sprocket engagement. Therefore, the pin needs high tensile and shear strength, resistance to bending, and also must have sufficient endurance against shock and wear.

- **Bushing**
  The bushing shown in fig. 3.3 is subject to shearing and bending stresses transmitted by the plate and Forged chain, and also gets shock loads when the chain engages the sprocket. In addition, when the chain articulates, the inner surface forms a load-bearing part together with the pin. The outer surface also forms a load-bearing part with the inner surface when the Forged chain rotates the links engages the sprocket. Therefore, it must have great tensile strength against shearing and be resistant to dynamic and shock wear. Some parts must perform two or more functions at the same time, and some of those functions may conflict with each other. For example, some parts must have high surface hardness to resist wear, but they must also have high ductility to withstand considerable bending. The chain designer is faced with a great challenge in deciding how to best serve all of the requirements.

- **Conveying capacity of chain**
  Conveying capacity of Chain is required to calculate the power required to convey the material. I have observed in industry that the conveying capacity of the Forged type of chain used in industry is 27.5 tones/hour.

- **Speed conveyor**
  Conveyor speed of Chain is required to calculate the power required to convey the material. Power required to convey the conveyor is directly proportional to the speed of conveyor. I have observed in industry that the conveyor speed of the Forged type of chain used in industry is 0.1667 meter/sec.

- **No. of strand**
  In The industry there are two chains are used to conveyor system. These conveyors are running on the guide ways. These two chains are running on the sprockets.

- **Power for present conveyor**
  Forged chains are used in the industry to convey the sugar Cane from one mill to another mill. These mills are situated by some height. Hence these materials (sugar cane) are transferred at that height. Power required because of inclination is more than that of plain material transfer. During industrial survey I have observed that power required to drive the conveyor is 25 KW i.e. 33.53 HP motor capacity is required; in the industry there is 35hp motor is used to drive the conveyor.

IV Design Process Based on Breaking Load

- **Total weight of chain**

Total weight = wt. of Link + wt. of Bush 1 + wt. of Pin + wt. of Bush 2
= 72.13466 kg
Total weight of present chain on both side of conveyor (Wc) = 2x72.13466 =144.2693 kg.

- **Chain pull (C_p)**

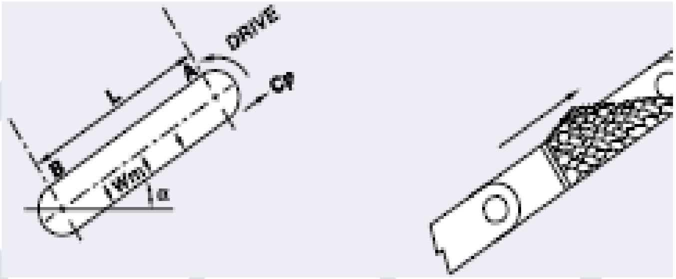


Fig. 4.1 Cain position at sugar factory

$C_p = 9.81 \text{ X L X}[(Wc \text{ X } \mu_{s2}) + (Wm \text{ X } \mu_{sm})] + P_B + X$
L − Length of the conveyor in meter
$\mu_{s1} = (\mu_c \text{ X } \cos\alpha) - \sin\alpha$
= (0.2 X cos 45) – sin 45
= -0.5657
$\mu_{s2} = (\mu_c \text{ X } \cos\alpha) + \sin\alpha$
= (0.2 X cos 45) + sin 45
= 0.8485
$\mu_{sm} = (\mu_m \text{ X } \cos\alpha) + \sin\alpha$
= (0.4 X cos45) + sin 45
= 0.9899
μ_c = coefficient of friction, chin on steel = 0.2(For occasional lubricating condition)
μ_m = coefficient of friction, load on steel = 0.4(wood, chips, finished cylendrical parts)
α = Angle of inclination(degrees)
= 450
Wc = Chain total mass per meter (kg/m)
Wm = Mass of load per meter (kg/m)
$P_B = 9.81 \text{ X L X Wc X } \mu_{s1}$
= 9.81 X 18.288 X 144.2693 X -0.5657 = -14641.8287 N
X = Extra chain pull due to side guide pull
= 0.25GLH2
G = Side friction factor = 0.01
H = Material height = 0.6096m
= 0.25 X 0.01 X 18.288 X (0.6069)2
= 0.01684 N
Cp = 9.81 X 18.288 X [(144.2693 X 0.8485) + (800 X 0.9899)] + (-14641.8287) + 0.01684
= **149394.2665 N or 15228.77 kg**
Two chains used on conveyor, hence chain pull on one chain = 74697.13N or 7614.3867kg factor safety

- **Breaking load**
  $Breaking\ Load = Chain\ pull(C_p) * Factor\ safety(8)$
  = 74697.13 X 8
  = 597577.04N or 60915.09 kg
  = **600000 N**
- **Power required for drive the chain**
  $P_o = \frac{Cp \times v}{1000}$ = **24.904 KW**
- **Design Stress**
  Tensile strength = 600 -700 N/mm^2, from design data book

$$\text{Design Stress} = \frac{\text{MaximumWorking stress}}{\text{Factorof safety}}$$

$$= \frac{700}{1.5}$$

$$= 466.67 \text{ N/mm}^2$$

V FINITE ELEMENT ANALYSIS

- **CAD model**

  As per the previous design and analytical result I had drown CAD model in the Pro-E software of cane carrier conveyor Forged chain link as shown in Fig. 5.1 and 3D Model in Fig. 5.2

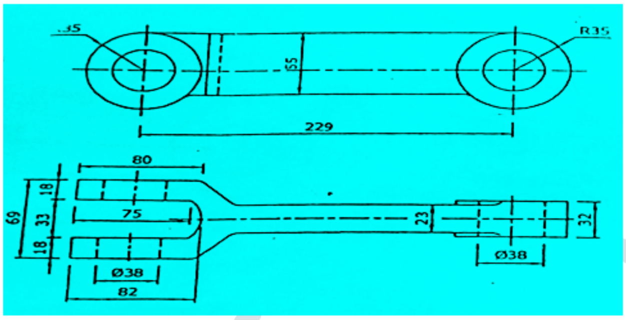


Fig. 5.1 Previous CAD Model

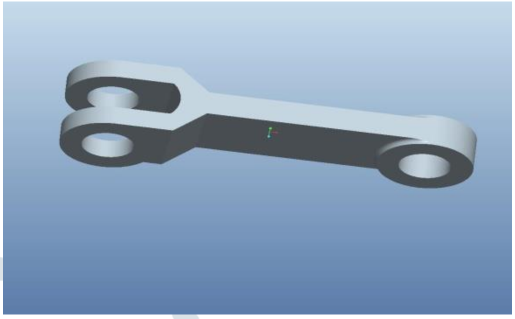


Fig. 5.2 3D CAD (Pro-E) model

- **Material Properties**

Material Property	Notation	EN9	Unit
Modulus of Elasticity	E	2.06×10^5	MPa
Poisson Ratio	MU	0.3	-
Density	ϱ	7800	Kg/m^3

- **Finite Element Analysis**

  Finite Element Analysis is carried out by using ANSYS Workbench 14.5 Software. The forged chain links to be optimized in this project are shown below Stages.

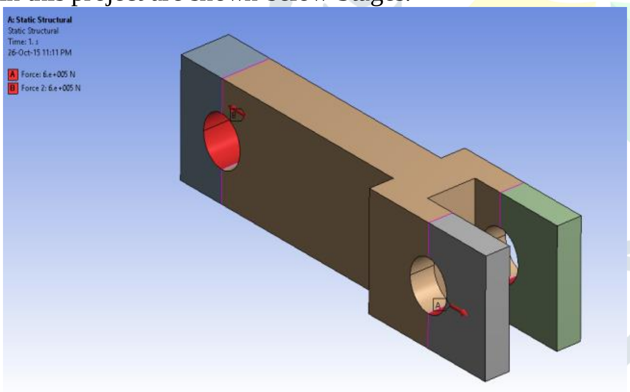


Fig. 5.3 Force Applied

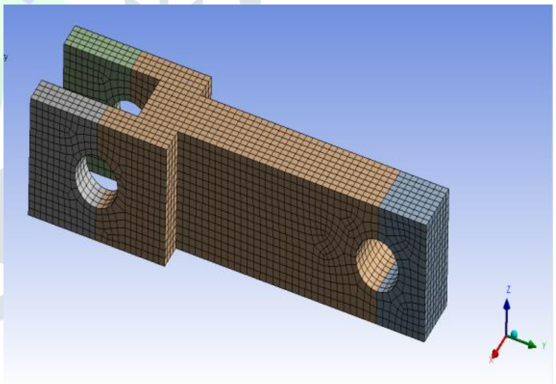
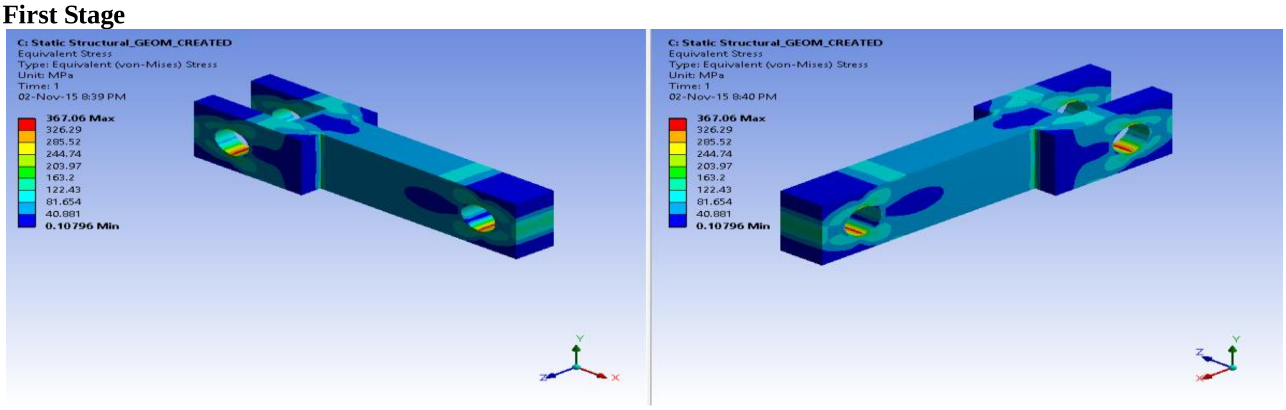


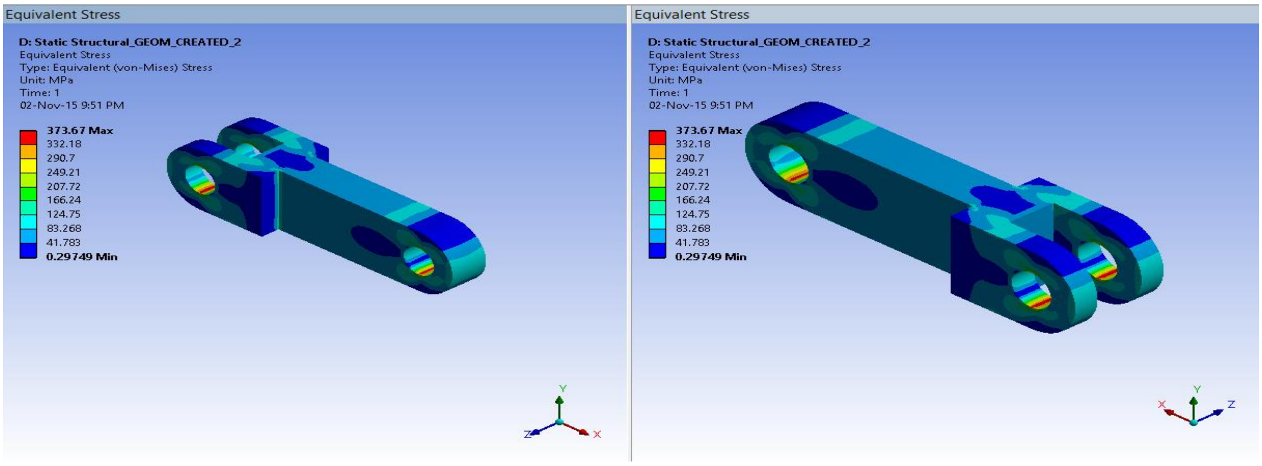
Fig. 5.4 Meshing Model

- **First Stage**



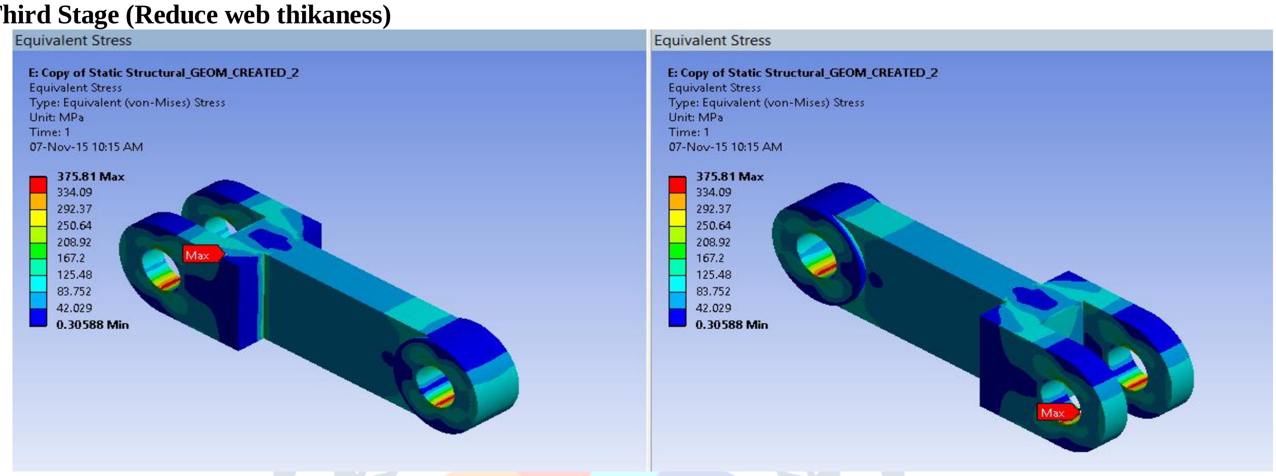
The maximum stress is 367.06 MPa and maximum deformation is 0.0780 mm.

- **Second Stage (Chamfering the Corner)**



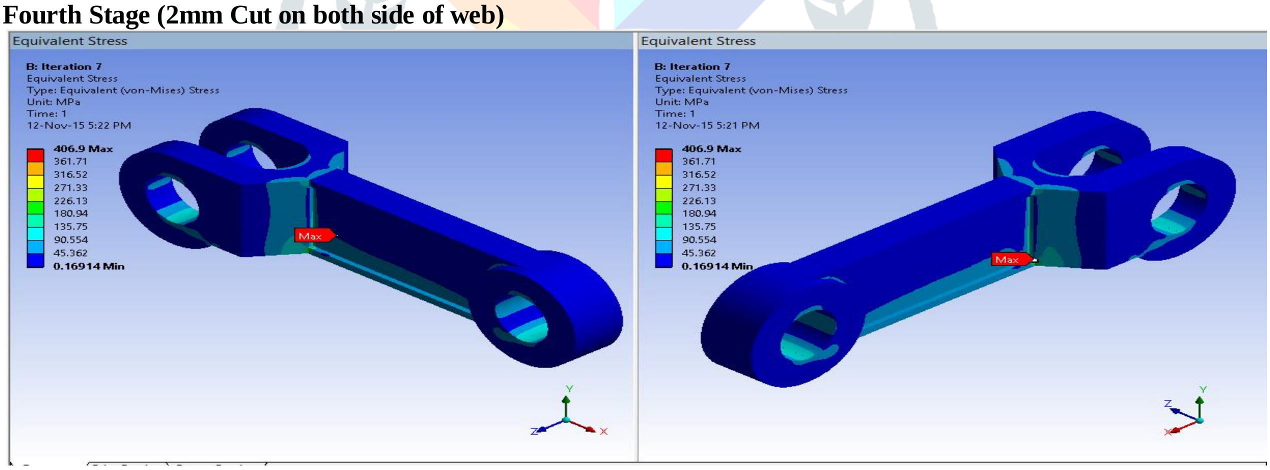
The maximum stress is 373.7 MPa and maximum deformation is 0.081 mm.

- **Third Stage (Reduce web thikaness)**



The maximum stress is 373.7 MPa and maximum deformation is 0.081 mm.

- **Fourth Stage (2mm Cut on both side of web)**



The maximum stress is 406.9 MPa and maximum deformation is 0.11 mm.

The stress and total deformation plots denote that the shape fourth stage link 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 forged chain link.

- **Percentage of weight reduced for one chain link**

$= \frac{\text{weight of origenal chain link} - \text{weight of optimised chain link}}{\text{weight of origenal chain link}} \text{X } 100\ \%$

$= \frac{0.780}{3.77} \text{X } 100\ \%$

= 20.68 %

- **Chain pull of optimized chain**

$Cp_o = 9.81 \text{ X L X}[\ (\text{Wc X } \mu_{s2}) + (\text{Wm X } \mu_{sm})] + P_B + X$ = **74158.7121 N**

- **Breaking load of optimized chain**

$\text{Breaking Load of optimised chain} = \text{Chain pull}(Cp_o) * \text{Factor safety}(8)$ = **593269.6968 N**

- **Power required for drive the optimized chain**

$P_o = \frac{Cp_o \times v}{1000}$ = **24.7245 KW**

- **Percentage of power consumption**

$$= \frac{P - P_0}{P} X\ 100\ \%$$

$$= \frac{24.904 - 24.7245}{24.904} X\ 100\ \%$$

$$= 0.72\ \%$$

VI. RESULTS & DISCUSSION

As shown Table 5.1 while comparing Finite Element Analysis result and Analytical results we can observe that optimized conveyor is having more load carrying capacity as well as less weight, low power is required to drive the conveyor because of less chain pull. Hence designed conveyor is optimum under given load of 60 tons.

TABLE: 5.1 Comparison between analytical and FEA results

Type ➡	Analytical Result	Finite Element Analysis Result	Remark
⬇ Property	Original Chain	Optimized Chain	
Chain pull (KN)	74.697	74.158	**Less on optimized chain**
Breaking Load (KN)	597.57	600	**Almost same**
Stresses (N/mm2)	466.67	406.9	**Almost same**
Power reduced (W)	--	179.5	**0.7% power is reduced**
Weight reduced/link (gm)	--	822.7	**20% weight is reduced**

VII Conclusion

As the Finite element analysis results are within calculated working stress, so the chain assembly was safe under the maximum working load of 608.86 KN. The weight saving is 20% 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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