# Design and Analysis of Drag Chain to Reduce Failure Modes for handling of Fertilizer Materials

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***Abstract*** **- According to the relevance towards the nation priorities, the economy of India is dominated by agricultural, industrial sector and livestock breeding. Cattle feed factories play an important role in economy of India. About 60% processes in these factories are based on drag chain conveyors. Apart from that, other industries also use these chains frequently for process atomization. However, failure of these chains is perennial problem in these industries which cause losses of industries and ultimately influence over economical growth of the nation.**

**Material uncertainty plays an important role on formation of elastic and plastic stress. The faulty manufacturing such as wall thickness of link, breaking area of links, bending movement of pin, inner width of chain and shape of the link and uncertainty in heat treatment was responsible root cause for break-down of the chain. We found the limited patents for the improvement of chain life as well as reduction in failure modes. Moreover, there is more scope in improving the strength of conveying system by using modified manufacturing as well as heat treatment process.**

**In the present study, the improvement of breaking load, reducing the percentage elongation and failure mode, increases the strength of drag chain conveyor system. We found that the maximum stress is 500 N/mm$^2$ for drag chain and for modified drag chain; it is 486.49 N/mm$^2$ by FEA. From these two values, it is cleared that stresses are reduced by 13.51 N/mm$^2$ in modified drag chain by FEA. Also, load carrying capacity is less in old drag chain, then by improving in manufacturing processes, mechanical properties and heat treatment processes, we can increase the strength and load carrying capacity of new drag chain by keeping the area and material same.**

***Key words: Drag chain conveyor, manufacturing process, heat treatment process, breaking load, mechanical properties, FEA.***

## I. INTRODUCTION

Drag conveyors have one or more endless strands of heavy duty chain that drags a bed of bulk material through a trough or enclosed casing. The chain moves the material due to the high internal friction of the material such as cement clinker and fertilizer products. Drag conveyors typically move the material over the bottom of the casing over the hardened wear blocks or smooth hardened plate depending on the specific material and in drag conveyors are well suited for applications that require multiple loading or discharge points, such as feed from in line storage silos. A drag conveyor is also used when dust control is critical and a totally enclosed casing is required.

Chain is one of the most widely used moving medium in material handling systems, being robust and very adaptable, but it is also one of the most neglected component with in such equipments when general or routine maintenance is carried out. In many cases this product is attended to when problem is occur, normally when the chain is already damaged or need corrective maintenance and required replacement. This research is based on how to improve the tensile loading capacity of the chain to prevent tensile failure. Chain links are machine elements that are subjected to extreme service conditions, such as high tensile loads, friction, and sometimes aggressive operating environment (e.g. presence of humidity, seawater, chemicals). Apart from tensile overload fracture, double shear is also an important failure mechanism which occurs under lower applied loads. As these chains operate under various forces, failure of chain assembly is the major problem. Causes of these failures are improper material selection, uncertainties in manufacturing, faulty manufacturing processes. Most of the time chain is under huge tension which causes elastic and plastic stresses which results into elongation of chain.

Material uncertainty plays an important role on formation of elastic and plastic stresses. Breakage of chain is also affected due to faulty manufacturing such as wall thickness of link, breaking area of links, bending movement of pin, inner width of chain and shape of the link and uncertainty in heat treatment. Strength of attachment is depends on welding, stress relief during tempering and weight of the attachment.

*Components of Drag Conveyor Chain:-*

Figure shows the drag chain components, it consists of Inner link plate, outer link plate, and pin, bush and split pin. The flights connected to outer link plate with the help of welding process. Its main function is to convey the material from one place to another place. Its failure occurs mainly due to overloading of material. The plate is the component that bears the tension placed on the chain. Usually this is a repeated loading sometimes accompanied by shock.


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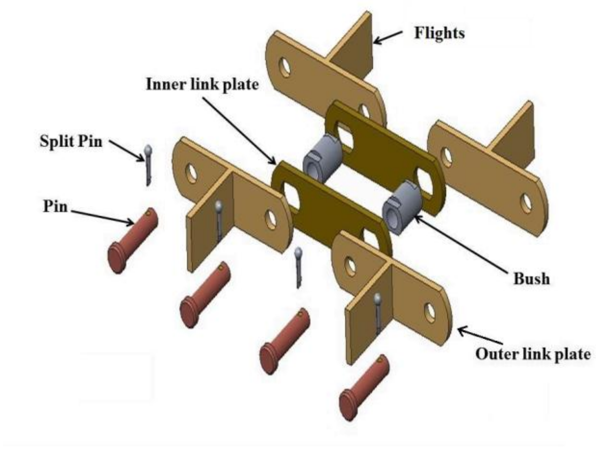


Fig.1 Components of Drag Conveyor Chain

The pin 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 shear strength, resistance to bending, and also must have sufficient endurance against shock and wear. The pin ends may be staked, spun or riveted. The bushing is subject to shearing and bending stresses transmitted by the plate and roller, 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 materials used for components of drag chain are as follows-

Table 1:- Materials of drag chain conveyor components.

| Sr. No. | Name of Drag Conveyor Chain Part | Material |
|---|---|---|
| 1. | Inner Link Plate | C45 |
| 2. | Outer Link Plate | C45 |
| 3. | Flights | C45 |
| 4. | Pin | 40Cr1Mo60 |
| 5. | Bush | 40Cr1Mo60 |
| 6. | Split pin | M.S. |

## II. DESIGN OF DRAG CONVEYOR CHAIN

2.1 Chain Velocity (v):

Velocity of the material determined by equation:

$v = Q/(HB\beta\gamma \times 3600) -----(1)$

β=0.5 to 0.6

$\gamma$=0.600 kg/m$^3$

$$v = 0.2480\, m/sec$$

2.2 Weight of Transported Material ($P_1$):

$P_1 = HBL\beta\gamma \times 1000$-------------- (2)

Where,

$L$=loaded length of conveyor (m)

$$P_1 = 0.28 \times 0.2 \times 10 \times 0.5 \times 0.6 \times 1000$$

=168 kg

$P_1$ =168×9.81=1648.08 N

2.3 Selection of Suitable Chain:

Breaking Strength ($F_b$) = $P_1$×k------------- (3)

Where,

K =safety coefficient =7

$F_b$=1648.08×7=11536.56 N

$F_b$=11.536 KN

As Bureau of Indian standard IS 13926: 2005 catalogue selected chain:

Chain Number=RK –PL-101.0
Pitch = 4"=102 mm
Breaking Load=11.53 KN
Diameter of Pin=15mm
Maximum outer width = $L_{max}$=50 mm
Diameter of bush=25mm
Minimum width of chain = $E_{min}$=22mm
Width of chain link plate = F=40mm
Thickness of chain link plate = T=5mm
Thickness of Flight = $T_1$=5mm

2.4 Chain Weight (P):

The selected weight per meter is q = 4.4 kg/m, its pitch is 102mm and assumed number of teeth is z =7.

$d_t = p/sin(180/Z)$ ------------------- (4)

$$d_t = 102/sin(180/7)$$

$d_t$ = 235.08 mm = 0.2358 m

Total length of chain:

L= 2×a+$\pi d_t$-------------- (5)

Where,

$a$ = 10m (length of drag conveyor)

L = 21.12m

Total load = P = L×q------------------ (6)

Where,

q = weight of chain per meter = 4.4 kg/m

P=21.12×4.4=92.92 kg

2.5 Selecting of friction coefficient(Fr):

The chain slides on even steel guide ways. The estimated reading of

Fr = 0.3------------------- (7)

2.6 Correction coefficient for type of operation:

Fs = 1.2 ------------------ (8)

2.7 Determination of velocity correction coefficient:

Fv = 1.0 --------------------- (9)

2.8 Friction coefficient:

Fm = 0.4 ------------------ (10)

2.9 Computation of traction force (T):

$T = \frac{9.81((P\times fr+P1\times Fm)Fs\times Fv)}{Number of chains}$ ----------- (11)

T=8082.49 N

2.10 Computation of necessary shaft power (N):

$N = (T \times v)/1000$ ---------------- (12)

$$N = (8082.49 \times 0.2480)/1000$$

N=2004W

N=2004/746=2.86

Hence we selected 3HP motor for driving the chain.

2.11 Calculation for Components of Chain:

Design of pin in shearing:

τ =$F/A$------------- (13)


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$=F/(2\times\pi/4\times d^2)$

According to max.Shear stress theory

$\tau=(Sut)/(f.s)$----------- (14)

For pin we selected material 40Cr1Mo60 at bar and forging hardened and tempered.

$S_{ut}$= 1150 N/mm$^2$

1Kgf = 10N

$\tau=F/(2\times A)$ $=F/(2\times\pi/4\times d^2)$

d = 14.46 mm

But from thecatalogue we select the suitable approximate standard value hence

d =15 mm

2.12 Sprocket:

The following formula can be used to determine the pitch outer and root diameter of a sprocket

From table we select the number of teeth 7 and n=2.305

$D_P = P/(Sin(180/7))$ -------------- (15)

$D_P = 102/Sin(180/7)$

$D_{P=}$ 235 mm

$D_e=D_p+(0.55/0.8)\times D$--------------(16)

From data table we select the diameter of chain roller

D=60 mm

$D_e$=235+(0.55/0.8)×60=276.25 mm

$D_i = D_P$-D =175 mm -------------- (17)

$D_P=P/((1/n))$----------------- (18)

$D_P= 102/((1/2.305))$ =235.11 mm

## Calculations Stresses for Chain Link Plate Assembly:

As per catalogue, we had taken chain link plate of C45 material, dimensions 40mm×102mm (pitch)× 5mm.Now by using the analytical formulaewe find out the value of maximum stress i.e. ultimate tensile strength.

Values from design data book,

Tensile strength = 63-71kgf = 630 N/mm$^2$ to 710 N/mm$^2$

Modulus of elasticity = 2.05×10$^5$ N/mm$^2$= 205,000MPa

Poisson's ratio = 0.3

Load carried by link plate,

Load carried by link plate= Permissible axial tension in plate × Pitch× Thickness of plate

= 160 × 102 × 5

= 81600 N = 81.6 KN

Since here are two pins per pitch length. The load carried by each pin is calculated as follows:

Load carried by each pin $=\frac{81600}{2}$

= 40800 N = 40.8 KN

By considering the coefficient of friction i.e. slip factor and factor of safety, Maximum permissible load on pin have been calculated as below:

Load carried by each pin $=\frac{\mu}{f.s}\times N\times T$

$40800=\frac{0.30}{1.5}\times 2\times T$

$T=\frac{40800\times 1.5}{0.3\times 2}$

T = 102000 N = 102 KN

As per above calculation the maximum load carried by assembly is 102000Nfor the dimensions of drag conveyor chain as per the Bureau of Indian Standards (BIS) Catalogue.

Maximum working stress for chain link assembly,

Maximum working stress = $\frac{\text{Working Load}}{\text{Resisting Area}}$

Maximum working stress= $\frac{102000}{40\times 5}$

= 510 N/mm$^2$

Minimum working stress for chain link assembly,

Minimum working stress = $\frac{\text{Working Load}}{\text{Resisting Area}}$

Minimum working stress = $\frac{80000}{40\times 5}$

= 400 N/mm$^2$

So as per the above analytical calculations, we got the maximum working stress of 510 N/mm$^2$ and minimum working stress of 400 N/mm$^2$. For checking this I have done the Finite Element Analysis for the working loads 20000N, 40000N, 60000N, 80000N and 100000N.

Working stress for 20 KN force**:**

Working stress = $\frac{\text{Working Load}}{\text{Resisting Area}}$

$=\frac{20000}{40\times 5}$

= 100 N/mm$^2$

Working stress for 40 KN force**:**

Working stress = $\frac{\text{Working Load}}{\text{Resisting Area}}$

$=\frac{40000}{40\times 5}$

= 200 N/mm$^2$

Similarly working stress values for 60kN, 80kN and 100kN are 300N/mm$^2$, 400N/mm$^2$ and 500N/mm$^2$ respectively.

## III. FEA ANALYSIS:-

*i. Mesh Generation:*

In this section, meshing for FEA is presented for the both drag conveyor chain assembly. In chain link assembly the pin is meshed by using triangular surface mesh and for other parts rectangular grid used as shown in fig.8.1. A material property of all parts has been entered as an input and 5mm element edge length is considered. 23777elements and 56456 nodes are generated to mesh the chain link assembly freely.

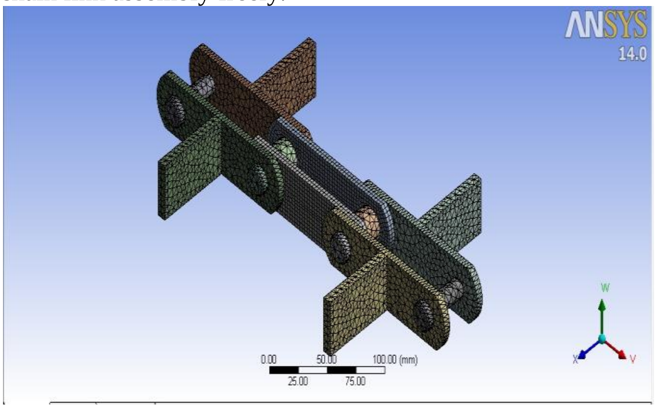


Fig. 8.1: Meshed model of chain link assembly



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*ii. Load & Boundary Conditions:*

A model of the drag conveyor chain link assembly created in modeling software using CATIA V5R17 is imported in ANSYS Workbench 15.0 using IGES files.

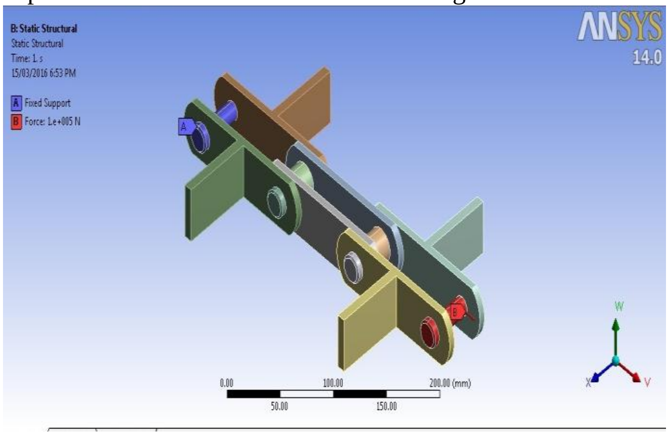
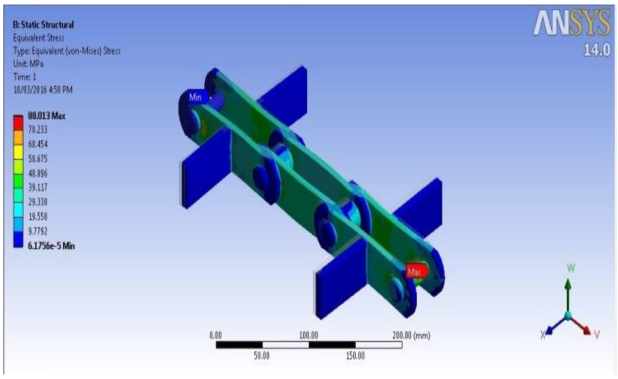



Fig. 8.2: Constraints and loading for chain link assembly

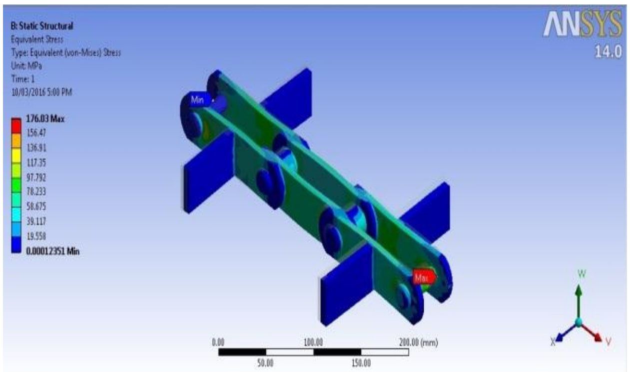
The constraints and loading conditions for chain link assembly has been shown in fig.8.2. The load is applied in the step of 20000N. As far as boundary conditions are concerned, finally 100000N load is applied in positive Y at one end of pin shown by red color. All degrees are made zero at the other end of pin.

*iii. Von Misses Stress Plots At Different Forces For Old Drag Chain Link Assembly:*

As shown in fig.8.3. Red color indicates there is maximum stress concentration at pin and the elliptical hole in the chain link plate. At a maximum load of 87000N it can sustain maximum stress of 440.06 N/mm$^2$.




(a)

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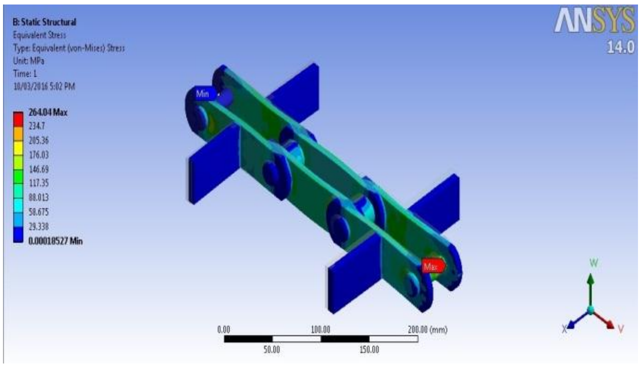


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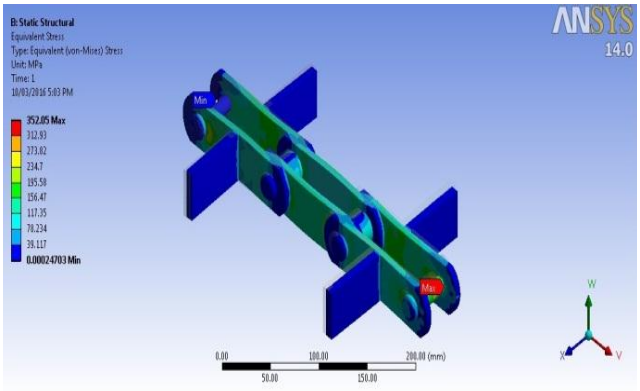
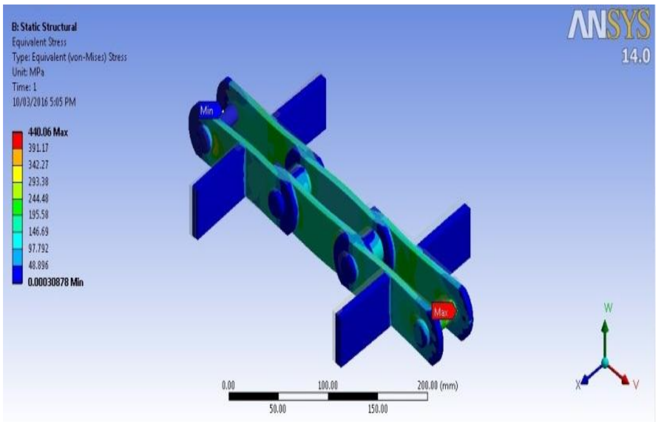



(d)




(e)

Fig. 8.3: Von misses stress plots at different forces for chain link assembly
a) F = 20000N b) F = 40000N c) F = 60000N
d) F = 80000N e) F = 100000N

*iv. Von Misses Stress Plots At Different Forces For New Drag Chain Link Assembly:*

As shown in Fig. 8.5 red color indicates there is maximum stress concentration at pin and the elliptical hole in the chain link plate. At a maximum load of 100000N it can sustain maximum stress of 486.49 N/mm$^2$.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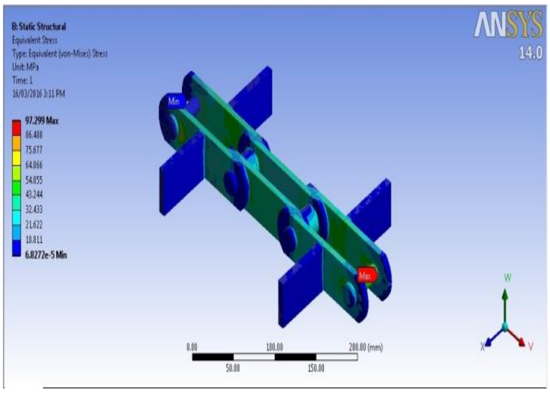
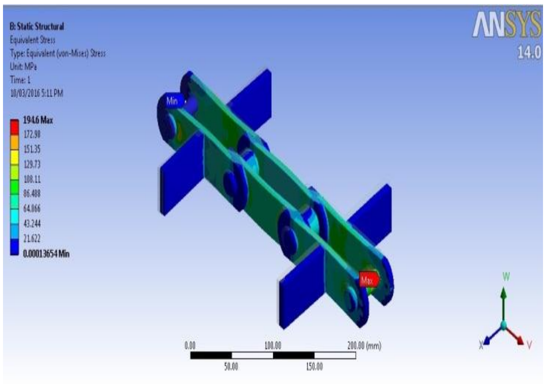



(a)

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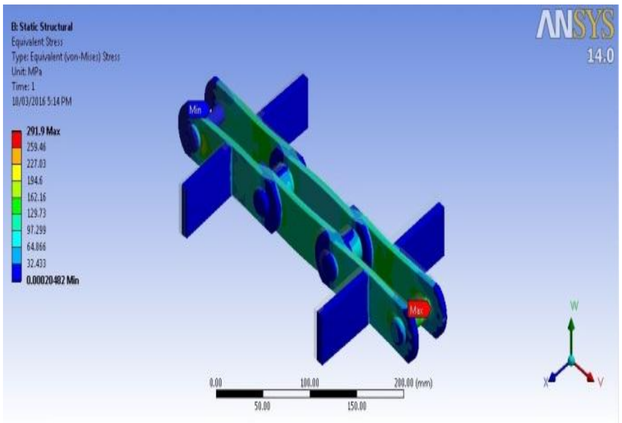


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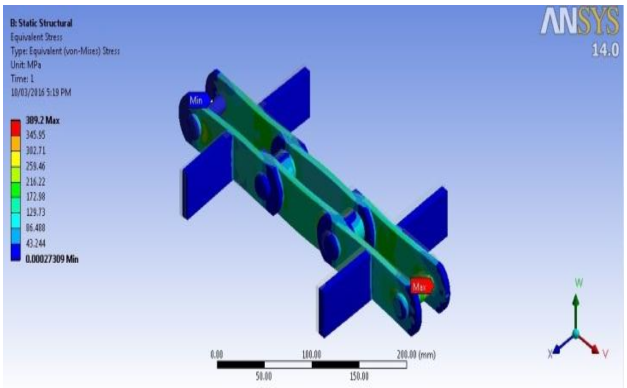


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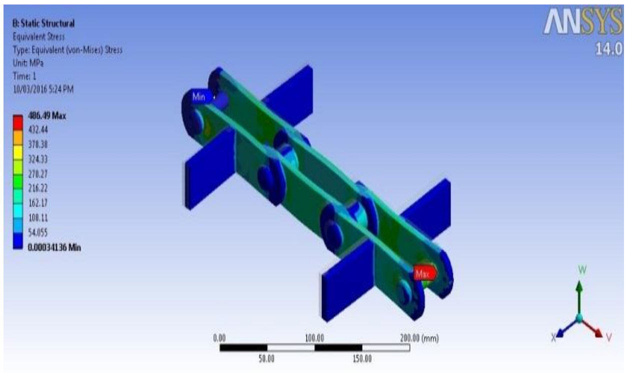


(e)

Fig. 8.5: Von mises stress plots at different forces for chain link assembly

a) F = 20000N b) F = 40000N c) F = 60000N
d) F = 80000N e) F = 100000N

## IV. NUMERICAL RESULTS AND DISCUSSION:

Finite element analysis has been carried for both old and new drag chain link assemblies. Von misses stress and displacement has been obtained for different force magnitudes. Below table gives the comparison results of von misses stress and theoretical stress for old and new drag chain link assemblies under different forces.

| Sr. No. | Force (KN) | Von Misses Stress (FEM) ($N/mm^2$) | Theoretical Stress ($N/mm^2$) | %Error |
|---|---|---|---|---|
| 1. | 20 | 88.01 | 100 | 11.99 |
| 2. | 40 | 176.03 | 200 | 11.98 |
| 3. | 60 | 264.04 | 300 | 11.98 |
| 4. | 80 | 352.05 | 400 | 11.98 |
| 5. | 100 | 440.06 | 500 | 11.98 |

Table 10.3: FEM result for old chain link assembly

Table 10.4: FEM result for new chain link assembly

| Sr. No. | Force (KN) | Von Misses Stress (FEM) ($N/mm^2$) | Theoretical Stress ($N/mm^2$) | %Error |
|---|---|---|---|---|
| 1. | 20 | 97.2 | 100 | 2.8 |
| 2. | 40 | 194.6 | 200 | 2.7 |
| 3. | 60 | 291.9 | 300 | 2.7 |
| 4. | 80 | 389.2 | 400 | 2.7 |
| 5. | 100 | 486.49 | 500 | 2.7 |

From the above tables, it is shown that percentage error is reduced in new drag chain link assembly as compare to the old chain link assembly. The finite element analysis gives maximum load carrying capacity of old chain is 87 KN and for new chain the maximum load carrying capacity increased up to the 100 KN.


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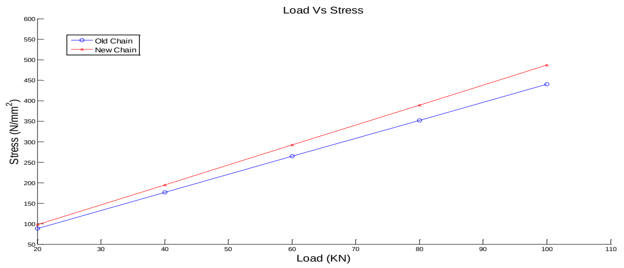


Fig. 8.2: Constraints and loading for chain link assembly

## V.CONCLUSION

It is concluded from the survey of fertilizer industry that major failure of drag chain conveyor is in tensile force. By theoretical method, we have found that the maximum stress is 500 $N/mm^2$ for drag chain and for modified drag chain, it is 486.49 $N/mm^2$ by FEA. From these two values, it is cleared that stresses are reduced by 13.51 N/mm2 in modified drag chain by FEA. Also, load carrying capacity is less in old drag chain, then by improving in manufacturing processes, mechanical properties and heat treatment processes, we can increase the strength and load carrying capacity of new drag chain and in this case, the area and material will remain constant.

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