# Design and Experimental Analysis of Flight of Drag Chain Conveyor Belt with respect to its Breaking Strength by Varying Materials

Mr. Harishchndra A. Shire [1], Prof. S. G. Ganiger [2]

JSPM'S Imperial College Of Engineering & Research, Wagholi, Pune 411 014, India

***Abstract*—Chain Conveyors are especially useful in applications involving the transportations of heavy or bulky materials. In industries generally consist of Drop Forged Mild Steel Links and Flights. The main concept in this paper is to vary the material of Flights to increase the breaking strength. Design and Analysis is carried out with Flight Materials such as Mild Steel, Aluminium Alloy and Composite Material (Glass Fiber Reinforcement Epoxy Resin). Impact of ribbing the Flight with two kinds of Flight material viz Aluminium Alloy and Composite Material (Glass Fiber Reinforcement Epoxy Resin) is also studied expecting ribbed Composite Material Flight to be the best with respect to its breaking strength. To accomplish the target, critical sections of existing Flight, interms of stress are found out and design is modified in those critical sections. For this, a 3D model of Flight is created in CATIA V5, Meshing is carried out in HYPERMESH and ANSYS is used for post processing.**

***Keywords*— Breaking Strength, Composite Material, Drag Chain Conveyor, Finite Element Analysis, Material Handling Equipement.**

## I. INTRODUCTION

A conveyor system is the most efficient medium of mechanical material handling equipment that conveys material from one place to another place. Conveyors are frequently useful in applications involving transportation of heavy or bulky material. There are different types of conveyor systems like Belt Conveyor, Chain Conveyor, Deep pan Conveyor, Gravity Conveyor System, Live Roller Conveyor and Screw Conveyor etc. Drag Chain Conveyor system can handle the material in horizontal Directions. Conveyor systems are generally used in various sectors including Automobile, Aerospace, Agriculture, Bottling and Canning, Cement industry, Chemical, Coal mine, Fertilizer, Food Processing, Heat Treatment Plant, Limestone, Print finishing and Packaging etc. The main purpose of such type of mechanical material handling equipment is to transfer goods with high efficiency, less material transport time, no need to slacken off the chain or retention while changing flights and easy installation. In fig.1 and fig.2 shows a Drag Chain Conveyor Flight Assembly for Mild Steel which is presently used in industries.

The main parts of the conveyor system are Chain links and Flights. In this paper the effort is focused on Flight of Drag Chain Conveyor System. There are different types of Flight systems based on the profile of conveyor, direction of material travel, carrying element etc. which include Square Bar Flight, Flat Bar Flight, L-Shape Flight, Paddle Flight, U-Flight, Closed U-Flight etc. In this paper use the L-Shape Flight.

Fig. 1 Flight Assembly

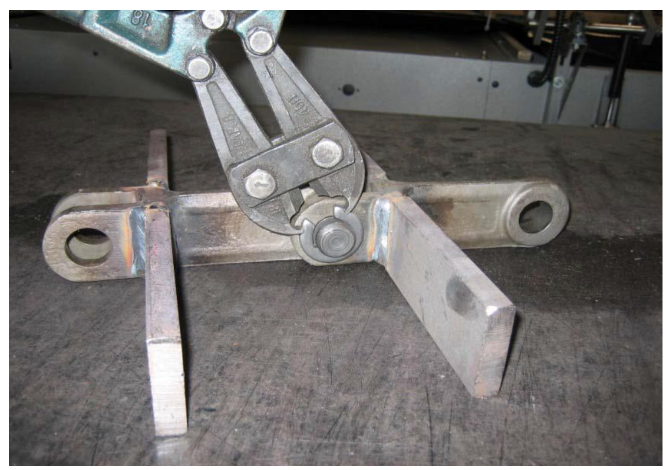

Fig. 2 Flight

## II. LITERATURE REVIEW

4B Group Manual [1]. This company is the manufacturer of forged chain chain links and pins, bolt and go chain and flight system, sprocket, trailers, accessories. This manual shows the design and specification of bolt and go conveyor and its advantages.

Hadwale U R et al [2]. Suggested to decrease overall weight of assembly and saving the materials by redesigning the existing gravity roller conveyor system and designing some critical parts like Roller, Shaft, Bearing and Frame.

Kulkarni S S et al [3]. The work has been carried out to increase chain link breaking strength from 40T to 70T without changing the pitch 216 mm. Mahindra Tsubaki Conveyor system currently used 40T breaking strength with 216 mm pitch. In the paper to increase the breaking strength of chain links from 40T to 70T by using two options (a) Option I: Change the existing dimensions with Conventional material. (b) Option II: Change the material of chain links with existing dimensions. In Option I must changes the parameters like to increase the Fork diameter, increase Fork thickness, increase Stress concentration factor and reduced the Pinhole diameter. The most disadvantage of option I is too new die is necessary. In option II there is no need of new die and goal is achieved by changing just material from 20MnCr5 to EN30B. Based on the above discussion we found that the option II is best suited as compared option I. In option I there is increase the weight and ultimately cost of new die. In option II there is totally eliminate the cost of new die and only changing the material of chain link while mating Strength requirement.

Martin Manual[4]. This compony is designing and manufacturing of Drag Conveyors more than 60 years manufacturing the Fort Worth Steels "Inclined Drag Flight Elevator".

Patil D et al [5]. Present to filled the $TiO_2$ and ZnS individually in Glass Fiber Reinforcement epoxy Composite and compare which one is better. Test results shown that the ZnS filled composite shows more sustaining or significantly higher values than $TiO_2$.

Robert M. Jones [6]. Author of book namely "Mechanics of Composite Materials" second edition. In this book details about the Composite material, its properties, limitations and applications.

Rexnord Manual [7]. This compony more than 100 years to primary source of Power transmission and conveying products for industries all around world.

Shinde S M et al [8]. Suggested to save 30.931% material by minimizing the overall weight of assembly to optimize such critical parts like Roller, Shaft, C-Channels for Chassis and Supports by studying conventional conveyor system.

Shirong Zhang et al [9]. Taking model based optimization approach to improve the efficiency of belt conveyor at the operational level from taking all parameter in four coeficient.

Wankhede V et al [10]. Work has been done to change the design of Drag Chain Conveyor for reducing the cost and to improve the performance. Changes the design of nut, split dowel pin with single circlip and tedious and costly external threading operation at the pin ends with simple turning operation, because of this changes saving material up to 4.5% in per meter length of chain and save the cost of operation.

Xiaolun Liu et al [11]. Work has done to increase the transmission Speed, reduced impact between plates and sprocket tooth and also reduced noise by using three types of conveyor Chains (a) A new type double pitch silent chain which is proposed by change some plates with Nano-Structured metal mesh-polyurethane composite material. (b) Double pitch roller chain. (c) Short pitch silent chain.

By comparing analysis result of all three types was found that the New type double pitch silent chain could effectively increase transmission speed and decrease the vibration and noise.

## III. OBJECTIVES

- To study the existing flight chain conveyor assembly.
- Design a Flight for increased load carrying capacity/ tonnage capacity.
- Replace conventional steel material of Flight with aluminium alloy and composite material (Glass Fiber Reinforced Epoxy Resin) to avoid corrosion, friction losses and reduce the weight.

## IV. METHODOLOGY

The Following six Steps are applicable for flight of each one of the three materials viz Mild Steel, Aluminium Alloy and Composite (Glass Fiber Reinforcement Epoxy Resin).

1. Study of Existing Drag Chain Conveyor Flight.
2. Design a CAD model of Flight in CATIA V5.
3. Meshing of Flight carried out in HYPERMESH.
4. FEA analysis of Flight using ANSYS.
5. Study the Stress and Displacement Plot
6. Numerical results will be validate with Experimental results.

## V. EXPERIMENTAL SET UP

Break load test will be carried out on Universal Testing Machine (UTM) which is shown in fig 3 below to check the breaking strength of Flight of drag chain conveyor system. The Specimen is placed in the machine between the grips and specimen.


Fig. 3 Image of UTM

TABLE I
SPECIFICATIONS OF UNIVERSAL TESTING MACHINE

| | | |
|---|---|---|
| Machine capacity | KN | 25 |
| No. of screw | | 2 |
| Maximum Testing Speed | Mm/min | 400 |
| Minimun Testing Speed | Mm/min | 0.1 |
| Voltage | Volts | 380-480: 3 phase |
| Current | Amp | 8 |
| Cycle | Hz | 50/60 |

## VI. MATERIAL SELECTION

### A. *Mild Steel*

At present drop forged flight chain assembly is made of mild steel material. So, first analysis is done using MS as material. Steel is the traditional material for drop forged flight chain assembly. Machinery to manipulate steel is easy to get and also it's cheap. This is the main reason that 99% of the drop forged flight chain assembly are made from steel. Steel is stiff but dense (heavy). Steel rates well in terms of both yield strength and ultimate strength, particularly if it's carefully alloyed and processed. Steel also resists fatigue failure well which is extremely useful - even if the assembly flexes under load, such flexing need not lead to a critical failure.

### B. *Aluminium Alloy*

Aluminium is very high corrosion resistance nonferrous material and very light material compared with steel. Strength-to-weight ratio of Aluminium can make it competitive with steel but cannot match the strength of steel. The density of aluminum is in the region of 35% of that of steel. Aluminum can also be alloyed and heat treated to improve it mechanical properties, which then makes it much more competitive with steels. Pure aluminum is also a possible material and is reasonably affordable and very light but it is the weakest and requires extra reinforcement to produce a rigid body. Aluminum is softer material and it is hard to work with requires welding skilled.

### C. *Composite Material (Glass Fiber)*

Composite material is the combination of two or more materials on macroscopic scale to form a third useful material. Composite materials are constituent of two materials (a) Matrix and (b) Reinforcement. The matrix material sustain and surrounds the other material by maintaining their comparative location. For involving matrix properties the reinforcement tell their physical and mechanical properties.

Glass Fibers are the most frequent of all reinforcing fiber for polymeric matrix composite. There are different types of polymer matrix material such as Epoxy, Phenolic, Polyester, Polyimide, Polyamide, Polypropetene, Vinyl ester etc. Fiber reinforced plastics have been commonly used for manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. Another related application for fiber reinforced polymeric composites (especially glass fiber reinforced plastics) is in the electronic industry, in which they are employed for producing printed wiring boards.

## VII. MATERIAL PROPERTIES

### A. *Mild Steel*

TABLE II
MATERIAL PROPERTIES FOR MILD STEEL AND ALUMINIUM ALLOY

| Properties \ Materials | Mild Steel | Aluminium Alloy |
|---|---|---|
| Young's Modulus | $2.1 \times 10^5$ MPa | 68.9 GPa |
| Poisson's Ratio | 0.3 | 0.33 |
| Density | 7850 $Kg/m^3$ | 2700 $Kg/M^3$ |
| Yield Stress | 250 MPa | 214 MPa |
| Ultimate Tensile Stress | 390 MPa | 241 MPa |

### B. *Composite Material (Glass Fiber)*

TABLE III
MATERIAL PROPERTIES OF COMPOSITE MATERIAL

| **Property** | **Value** |
|---|---|
| Longitudinal Modulus, $E_1$ | 59 GPa |
| Lateral Modulus, $E_2$ | 20 GPa |
| Poisson's Ratio , μ | 0.35 |
| Longitudinal Tension Strength, $X_t$ | 2000 MPa |
| Longitudinal Compression Strength, $X_c$ | 1240 MPa |
| Transverse Tension Strength, $Y_t$ | 82 MPa |
| Transverse Compression Strength, $Y_c$ | 200 MPa |
| Density, ρ | 2020 $Kg/m^3$ |
| In Plane Sher, s | 165 MPa |

## VIII. Numerical Analysis

### A. CAD Model

Dimensions of the Flight assembly is taken from the compony catalogue and model is created in CATIA V5 R20 software.

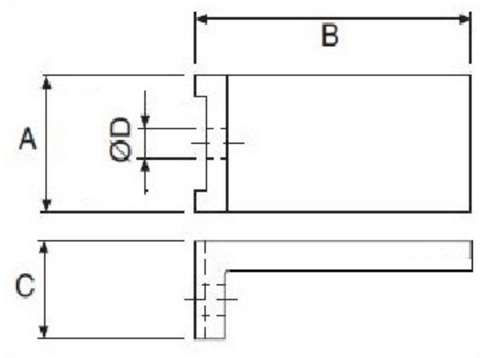


Fig4. “L” shape with one fixing hole.

A - 60 mm, B -500, C-114.5mm, D-15mm
Bolt Size: ISO M16X150

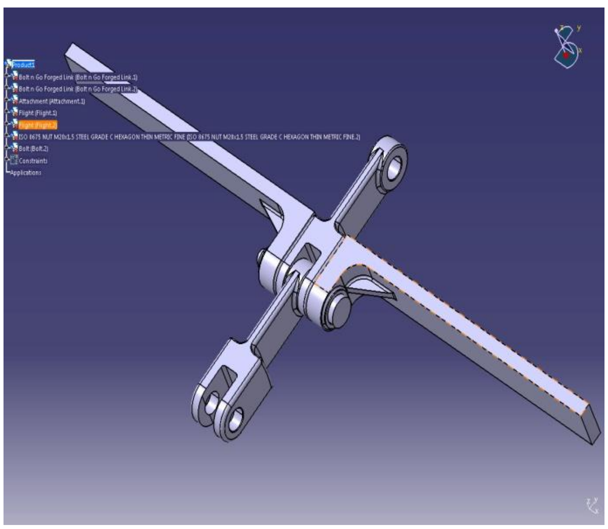

Fig. 5 Drop Forged Flight Assembly.

### B. Meshing Model

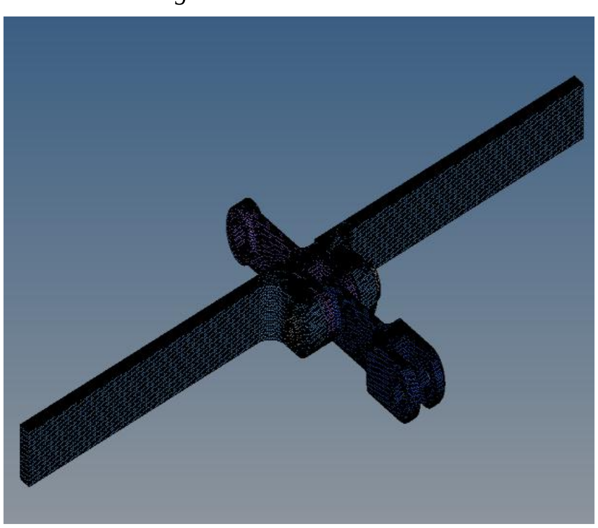

Fig.6 Meshed model of Drop Forged Chain Flight Assembly.

### C. Boundary Conditions

Apply the boundary conditions after completion of meshing. These boundary conditions are the reference points for calculating the results of analysis. In short we here go for the preparation of ornament. Here we define and apply various loads. Applied the different load steps which are created during analysis. Here surrounding effect is been taken into consideration while applying loads. Elements are defined by their properties. Material properties such as density, Poissons ratio and modulus of elasticity etc is assigned to the elements. Here proper arrangements are made so that we can run the analysis in solver software. After the completion of process model is exported to the solver.

### D. Boundary Condition Calculation

Considering, Cast Iron Boring as conveying material.
Density of cast iron borings = 3200 kg/m3
Fin to fin distance = 200 mm
Volume of fins can be found by its dimensions as = 0.2 X 0.5 X 0.02

= 0.02m3

We know,
Mass = density X volume
Mass = 3200 X 0.02
= 64 Kg
= 630 N

Considering uniformly distributed load on the fins and constraints as shown in below fig analysis can be done.

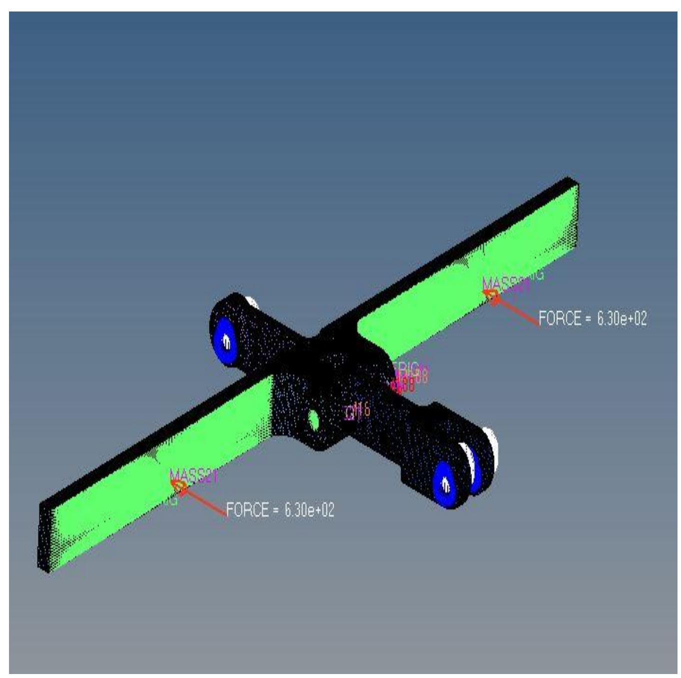


Fig. 7 Constraints and forces applied on model in Hypermesh.

*E. Stress and Deformation Results for Mild Steel (MS)*

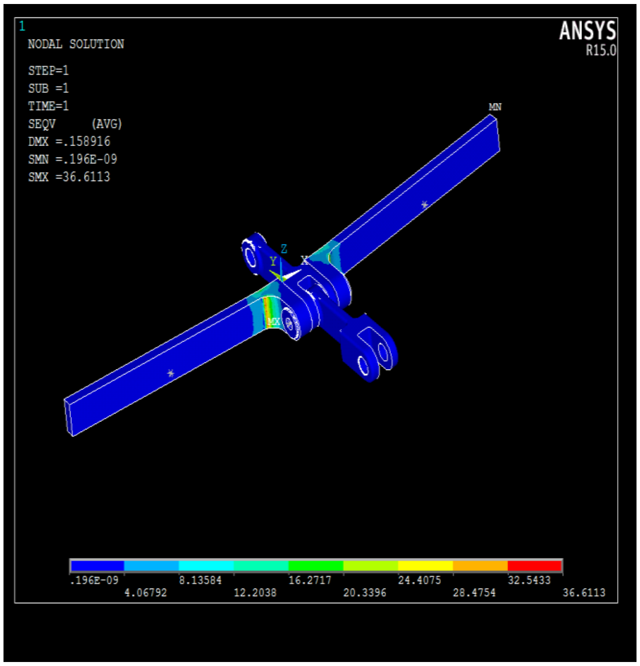


Fig. 8 Von-mises stress for Drop Forged Chain Flight Assembly.

Maximum Stress Value for Drop Forged Chain Flight Assembly is 36.61 N/mm$^2$ which is less than their respective permissible yield stress value. Hence our design is safe.

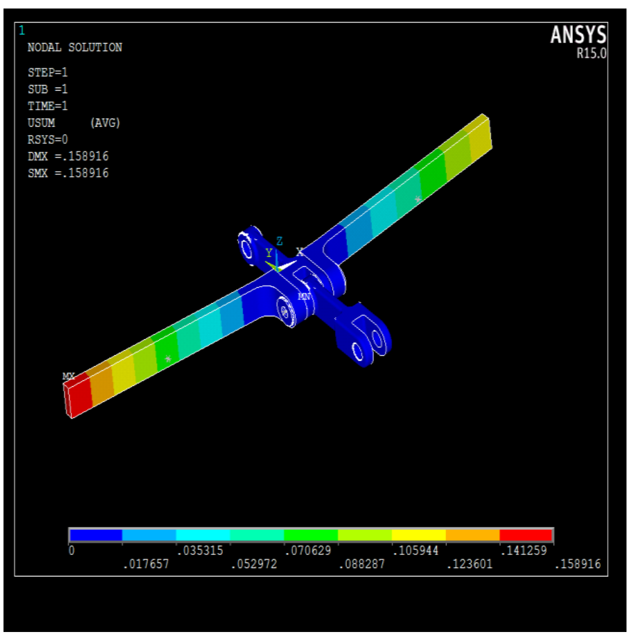


Fig. 9 Displacement result for Drop Forged Chain Flight Assembly.

From fig, deformation for Drop Forged Chain Flight Assembly is 0.15 mm

*F. Stress and Deformation Results for Aluminium Alloy*

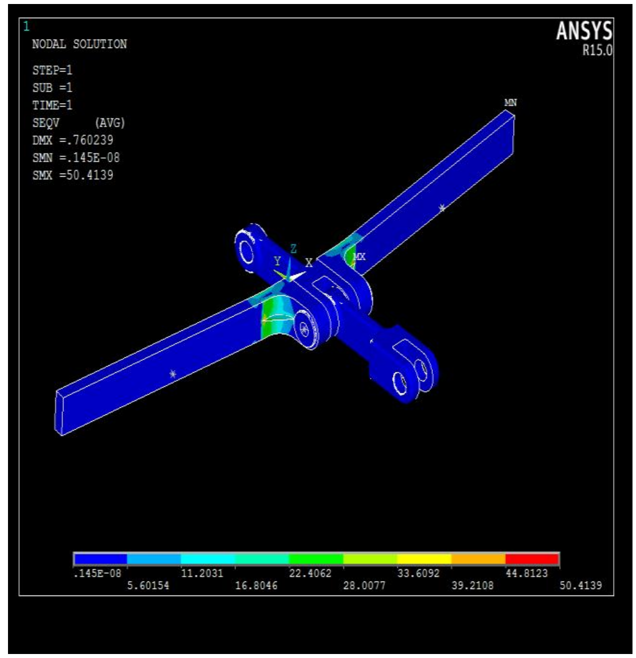


Fig. 10 von-mises stress for Drop Forged Chain Flight Assembly (Aluminum Alloy).

Stress value for Drop Forged Chain Flight Assembly is 50.41 N/mm$^2$ which is well below the critical value. Hence, design is safe.

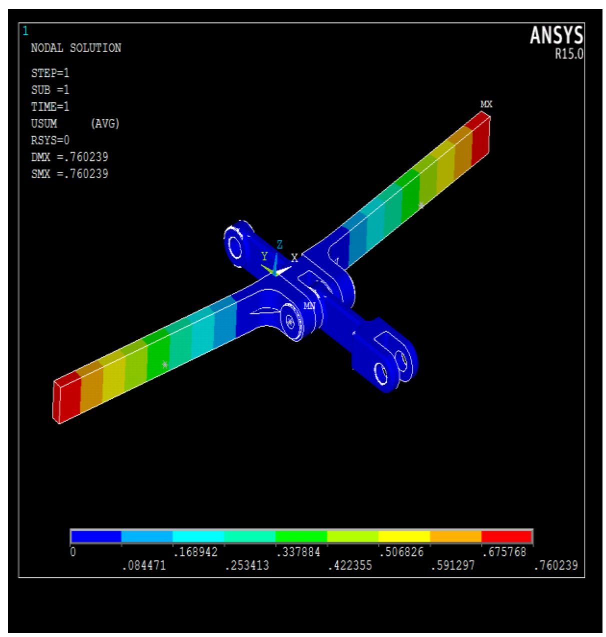


Fig.11 Displacement result for Drop Forged Chain Flight Assembly (Aluminum Alloy).

From fig, deformation for Drop Forged Chain Flight Assembly is 0.76 mm.

G. Stress and Deformation Results for Composite Material (Glass Fiber)

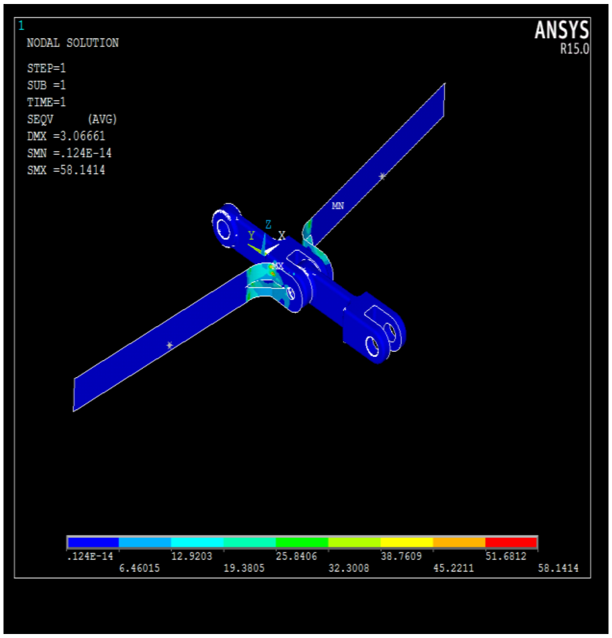


Fig12. von-mises stress for Drop Forged Chain Flight Assembly (Glass fiber).

Stress value for Drop Forged Chain Flight Assembly is 58.14 $N/mm^2$ which is less than the Yield stress value. Hence the design is safe.

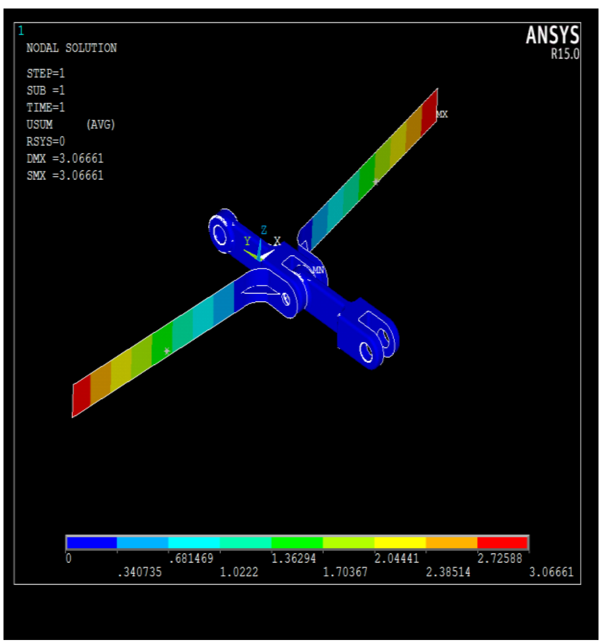


Fig. 13 Displacement result for Drop Forged Chain Flight Assembly (Glass Fiber).

From fig, deformation for Drop Forged Chain Flight Assembly is 3.06 mm.

## IX. RESULT AND DISCUSSION

The Drop Forged Chain Flight Assembly Analysis has been done for all three kind of materials viz. Mild Steel, Aluminium Alloy 6063 and Composite Material (Glass Fiber). The comparison of properties and analysis results is shown in table IV.

TABLE IV

COMPARISON OF ANALYSIS RESULTS

| Sr. No. | Material | Max Stress | Max Displacement |
|---|---|---|---|
| 1. | Mild Steel | 36.61 MPa | 0.15 mm |
| 2. | Aluminium Alloy 6063 | 50.41 MPa | 0.76 mm |
| 3. | Glass Fiber | 58.14 MPa | 3.06 mm |

From results of finite element analysis it is observed that stresses are maximum at joint locations. It is also observed that all the materials have stress values less than their respective permissible yield stress values. So the design is safe.

From analysis results and comparison of properties of all the all the materials, it is found that Glass Fiber is the material which is having the least density; also it is easily available and cheap as compared to other alternate materials. Also machining cost for Glass Fiber is less. Hence it is the best suited alternate material for Drop Forged Chain Flight Assembly and is expected to Perform better with satisfying amount of weight reduction and breaking strength.

## X. CONCLUSION

- From the analysis result it is clear that design for drop forged chain flight system for all three materials i.e. Mild Steel, Aluminium Alloy and Glass Fiber are safe.
- From these Materials as the density of Glass Fiber is lesser compared to other material, also Glass Fiber has high strength than other two materials.
- An attempt is made to increase the strength of flight chain assembly by adding a rib at the place of concentrated stresses.
- Results for von mises stresses with rib for Aluminium Alloy and Glass Fiber material is under safe limit.
- Hence we conclude that among three different materials, Glass Fiber is the best suited material for drop forged chain flight assembly.

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