Design and Analysis of Hybrid Composite Chain Link

Tushar C. Mali¹, Prof. Dr. A. D. Desai², P.G. Sarasambi³
¹PG Student, ²Professor, ³Asst. Professor, Mechanical Dept., Shree Ramchandra College of Engineering, Lonikand (Pune), SPPU, India

Abstract—Every consumer industry have a part of Material Handling. There is no matter what product is produced, at some time in its production way it is likely to be transported or stored by material handlers. Chain is the most important element of the industrial processes required for transmitting power and conveying of materials. Roller conveyor chain performs efficient and economical in wide range of applications in manufacturing industries. Chain drives are most important systems used in industry to carry the products and to transmit the power.

In this paper we perform, theoretical analysis of the stresses in chain link, pin and estimation of required strength as per given capacity of roller conveyor chain, finite element analysis of stresses in chain link for traditional material and hybrid composite material using ANSYS. Then Experimental analysis of chain link suggested alternative composite material is to be carried out and comparison of theoretical, FEA and experimental results for Chain Link Plate made of Hybrid composite will lead to the conclusion of the study and final results.

Keywords- Chain Link, Hybrid Composite Material , FEA, mechanical experiments

I. INTRODUCTION

A) Composite Material :

A composite material is a material system which consists of a mixture or a combination of two distinctly differing materials which are insoluble in each other and differ in form or chemical composition. Composite materials include of layers of at least two completely different materials that are bonded together. Thus, a stuff is labeled as any material consisting of two or more phases .Many combinations of material may, therefore, be termed as composite materials, such as concrete, mortar, reinforced rubbers, conventional multiphase alloys, fiber reinforced plastics, and fiber reinforced metals and similar fiber impregnated materials. Two-phase composite materials are broadly classified into two categories: particulate composites and fiber reinforced composites. Particulate composites are those in which particles having various sizes and shapes are dispersed with in a matrix in a random fashion. As the distribution of the particles are random and are of various shapes and sizes, these composites are treated as quasi-homogeneous and quasi-isotropic.

Examples of particulate composites are mica flakes reinforced with glass (non-metallic particles in a non-metallic matrix), aluminium particles in polyurethane rubber (metallic particles in a non-metallic matrix), lead particles in alloys (metallic particles in a metallic matrix) and silicon carbon particles in aluminium (non-metallic particles in a metallic matrix).

Some of the properties that can be improved by forming by composite material are:

- Strength
- Stiffness
- Corrosion resistance
- Wear resistance
- Weight
- Fatigue life
- Temperature dependent behavior
- Thermal insulation
- Thermal conductivity

B) Chain background :

A chain is a reliable machine component, which transmits power by means of tensile forces, and is used primarily for power transmission and conveyance systems. The function and uses of chain are similar to a belt.

Fig. 1 shows the basic structure of chain. In chain structure having parts called pin, roller, bushing, links, locking plate.
C) Features of Chain Drives:
1. Speed reduction/increase of up to seven to one can be easily accommodated.
2. Chain can accommodate long shaft-center distances (less than 4 m), and is more versatile.
3. It is possible to use chain with multiple shafts or drives with both sides of the chain.
4. Standardization of chains under the American National Standards Institute (ANSI), the International Standardization Organization (ISO), and the Japanese Industrial Standards (JIS) allow ease of selection

D) Points of Notice:
1. Chain has a speed variation, called chordal action, which is caused by the polygonal effect of the sprockets.
2. Chain needs lubrication.
3. Chain wears and elongates.
4. Chain is weak when subjected to loads from the side. It needs proper alignment.

II. Literature Review

Composite materials are preferred in places where lighter materials are desired or required without sacrificing strength. They have even become essential for many applications. Composite materials are being used in a variety of applications such as the structural parts of aircrafts, automobiles, chemical equipment, transformer tubes, boats, etc. Some transmission gears make use of plastic materials in many different places such as watches, instruments, types of washing machines, gear pumps, etc. Composite materials are efficient in applications that required high strength to weight and stiffness to weight ratios. However the available literature is relevant to the modelling and to study the displacements.

A. S. Singh and Vijay Kumar Thakur, (2008) discussed on mechanical properties of natural fiber reinforced polymer composites. Natural fibres offer a number of advantages over traditional synthetic fibres. Present work reveals that mechanical properties such as tensile strength, compressive strength and wear resistance etc of the urea–formaldehyde resin increases to considerable extent when reinforced with the fibre. Thermal (TGA/DTA/DTG) and morphological studies (SEM) of the resin and bio composites have also been carried out. Results suggest that Hibiscus sabdariffa fibre has immense scope in the fabrication of natural fibre reinforced polymer composites having vast number of industrial applications [1].

Barge P.R. and Gaikwad M.U. (2016) discussed about Roller Chain Link Plate used in Sugar Industry Chain Link assembly is extensively used in the sugar industry. It was determined that maximum amount of weight of chain conveyor is covered by the roller chain link plate Finite Element Analysis (FEA) has used to conduct shape optimization and weight optimization of roller chain outer link plate. We have concentrated on outer link plate and weight reduction of link plate by changing the shape of outer link plate. The aim of this paper is design optimization of roller chain link plate. In this paper the analytical and numerical methods are used for optimization of roller chain link plate. Also the experimentation has done to check validation of the work. The advantage of this paper is that it saves 72gm of weight per link plate and 1.2 kg per meter length of chain [2].

Dinesh Borse and Prof. Avinash Patil, (2017) described how to reduce weight of chain using different materials. They used different materials for optimize weight of chain link by doing comparative study. 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 [3].

Dr. Miller at. el. (2006) discussed about Analysis of High strength glass fibre. Continuous glass fibers, first conceived and manufactured during 1935 in Newark, Ohio, started a revolution in reinforced composite materials which by 2000 led to a global annual glass fiber consumption of 2.6 million tons. During 1942 glass fiber reinforced composites were first used in structural aerospace parts. In the early 1960’s high strength glass fibers, S Glass, were first used in joint work between Owens Corning Textile Products and the United States Air Force. Later in 1968 S-2 Glass® fibers began evolving into a variety of commercial applications. High strength glass fibers combine high temperature durability, stability, transparency, and resilience at a very reasonable cost-weight-performance. The utility of high strength glass fiber compositions are compared by physical, mechanical, electrical, thermal, acoustical, optical, and radiation properties [4].

Dr. P V Senthil and Aakash Sirsshti, (2014) discussed on studies on material and mechanical properties of natural fiber reinforced composites. Natural fibers have been used to reinforce materials for over 3,000 years. More recently they have been employed in combination with plastics.
Application of composite materials to structures has presented the need for engineering analysis, the present work focuses on the fabrication of polymer matrix composites by using natural fibers like jute, coir, and hay which are abundant in nature in desired shapes by the help of various structures of patterns and calculating the material characteristics (flexural modulus, flexural rigidity, hardness number, % gain of water, wear resistance, bonding structure) by conducting tests like flexural test, hardness test, water absorption test, wear test, SEM analysis and their results are measured on sections of the material and make use of the natural fiber reinforced polymer composite material for automotive seat shell manufacturing [5].

Hong Li at. el. (2014) studied about Glass fiber and glass fiber-reinforced plastic (GFRP). Composite industries have been enjoying continuous growth globally, especially in the most recent decade. This article is intended to provide a general review, with examples, of the history of fiber glass development as well as recent development. The review will cover glass fiber chemistry and composition design, mechanical property characterizations, and topics relevant to glass melting and fiber forming. This article by no means provides a comprehensive review on the subject; rather, it provides researchers and professionals with an update on the state of glass fiber technology with a focus on fibers with improved mechanical properties. The article is divided into four major sections: (i) overview of glass fibers, (ii) chemical approach to glass fiber mechanical performance, (iii) glass fiber mechanical property characterizations, and (iv) glass [6].

M. Muthuvel at. el. (2013) discussed about characteristics of jute fiber. The aim of the present work was to investigate the hybridization of glass fibers with natural fibers for applications in the aerospace and naval industry. Mechanical properties such as tensile, impact and flexural test of hybrid glass/jute fiber reinforced epoxy composites in the forms of lamina and laminates were determined. The lamina prepared with natural fiber mat showed lower mechanical properties compared to laminas with glass mat. For this reason we proposed to use a hybrid design for the various applications which makes use of glass woven fabrics and jute fiber mats. The adoption of this design allowed for a cost reduction of 20% and a weight saving of 23% compared to the current commercial solution. Laminates were fabricated by hand lay-up technique in a mold and cured under light pressure for 1h, followed by curing at room temperature for 48 h. All the laminates were made with a total of 10 plies, by varying the number and position of glass layers so as to obtain six different stacking sequences. One group of all jute laminate was also fabricated for comparison purpose. Total fiber weight fraction was maintained at 42%. Specimen preparation and testing was carried out as per ASTM standards [7].

M. Ravi Teja Reddy at. el. (2016) discussed about chain of different material. As of today, over 0.2 billion two wheelers are being used across the world. One of the important components for the power transmission that is an integral part of all two wheelers is the chain drive. The amount of torque that the chain drive delivers is the important determining factor for speed, acceleration and performance of a two wheeler. The present work is aimed at designing and analysis required to decide the capacity of a chain drive that should be used to drive a vehicle of particular specifications. Structural analysis was carried out for Chain links of different materials Aluminum 7475-T761alloy and Stainless steel. Stainless steel resulted as with less stress distribution and depending upon the stress acting on the Chain link, corresponding dimensions were determined [8].

Tushar Bhoite at. el. (2012) Discussed about review the applications in the industry and explore the design considerations that go into the design of the assembly. The paper delves into various application aspects and manufacturing aspects to formulate an idea of the system. Finally Finite Element Analysis (FEA) has been used to conduct shape optimization. Since lot of work has already been done in other components, in this paper the focus has been narrowed down to specific component of outer link [9].

III. PROBLEM STATEMENT AND OBJECTIVES

A) Problem Statement:

Chains are machine elements that are subjected to extreme service conditions, such as high tensile loads, compressive loads, friction, and sometimes aggressive operating environment. Satisfactory level of materials we are using till now for chains are not sufficient so it’s necessary to find a new material that will match with strength requirement of Chain linkages.

B) Objectives :

1) To study Background of chain linkages
2) To study existing model; modeling and analysis of considered component.
3) Study load carrying capacity of existing chain conveyor by proposing suitable design and make some modification as per the application.
4) Develop finite element model for composite structure subjected to a point load and uniformly distributed temperature.
5) Investigate the behavior of the laminated composite under tensile, flexural, impact loading conditions.
IV. CAD MODEL

Design of chain using catia software:

Fig. 2 shows the CAD model which is designed using design data book and Iwis handbook for chain engineering design and construction.

Fig. 2 - CAD model-Assembly Chain link

V. FINITE ELEMENT ANALYSIS

A) Geometry:

Geometry is taken as per design and imported as step file.

Fig. 3 - Geometry of chain link

Fig. 3 shows geometry of chain link. We design this chain for coal transportation in suger factory. By input and hand calculation we found transporting load is 11679N and breaking load is 35037N by using FOS is 3. By using breaking load we found M128 A SL/ANSI 60/DIN8188 chain is useful for given input.

B) Total deformation analysis:

Fig. 4 - Total deformation analysis of stainless steel chain link

Fig. 5 - Total deformation analysis of carbon fiber chain link

Fig. 6 - Total deformation analysis of Jute 50% E glass fiber chain link

Fig. 7 - Total deformation analysis deformation Polyester and Continuous Roving Laminate 70% E glass fiber chain link

From fig. 4,5,6 and 7 shows total deformation analysis of respective materials. Analysis showing total deformation is 0.05476 mm, 0.2365 mm, 0.3921 mm and 0.04333 mm respectively.

C) Von Mises Stress Analysis:

Fig. 8, 9, 10 and 11 shows von mises stress analysis of respective materials. Analysis showing stress 1134.1 Mpa, 1768 Mpa, 1100.1 Mpa and 1122 Mpa respectively.
D) Equivalent Elastic Strain Analysis:

Fig. 8- Von mises stress analysis of stainless steel chain link

Fig. 9 - Von mises stress analysis of carbon fiber chain link

Fig. 10- Von mises stress analysis of Jute 50% E glass fiber chain link

Fig. 11- Von mises stress analysis of Polyester and Continuous Roving Laminate 70% E glass fiber chain link

Fig. 12- Equivalent elastic strain analysis of stainless steel chain link

Fig. 13 - Equivalent elastic strain analysis of carbon fiber chain link

Fig. 14 - Equivalent elastic strain analysis of Jute 50% E glass fiber chain link

Fig. 15- Equivalent elastic strain analysis of Polyester and Continuous Roving Laminate 70% E glass fiber chain link
From fig. 12, 13, 14 and 15 shows equivalent elastic strain analysis of respective materials chain link. Analysis showing Equivalent elastic strain 0.0058 mm/mm, 0.07818 mm/mm, 0.04152 mm/mm and 0.0046 mm/mm respectively.

E) Shear Stress Analysis :

From fig. 16, 17, 18 and 19 shows shear stress analysis of respective materials. Analysis showing shear stress 481.89 Mpa, 387.13 Mpa, 480.82 Mpa and 450.32 Mpa respectively.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Material</th>
<th>Displacement (mm)</th>
<th>von Mises Stress (Mpa)</th>
<th>Equivalent elastic strain (mm/mm)</th>
<th>Shear Stress (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stainless steel</td>
<td>0.05476</td>
<td>1134.1</td>
<td>0.0058</td>
<td>481.89</td>
</tr>
<tr>
<td>2</td>
<td>Carbon fiber</td>
<td>0.2365</td>
<td>1768</td>
<td>0.07818</td>
<td>387.13</td>
</tr>
<tr>
<td>3</td>
<td>50% E glass and 50% Jute</td>
<td>0.3921</td>
<td>1100.1</td>
<td>0.04152</td>
<td>480.82</td>
</tr>
<tr>
<td>4</td>
<td>polyester and 70 % E-glass</td>
<td>0.04333</td>
<td>1122</td>
<td>0.0046</td>
<td>450.32</td>
</tr>
</tbody>
</table>

VI. EXPERIMENTAL TESTING AND VALIDATION

A) Material preparation and its microstructure:

To perform mechanical testing we prepare specimens of materials. Also check its microstructure.

Composition of materials:

a) Glass fiber + polyester :
Rowen woven Glass fibers (70%) + Polyester Resin 2% of Cobalt added (30%) + Hardener 2% of total mixture
No of layers: 8 for 3 mm thickness.
Layers arranged in Matrix form.
If 1st layer is 90 degree, next layer of 0 degree.

b) Glass fiber + jute :
Glass fiber (50%) + jute (50%) + Epoxy Resin + Epoxy Hardener Ratio of 2 : 1 respectively
No of layers: 7 for 3 mm thickness.
Layers arranged in Matrix form.
If 1st layer is 90 degree, next layer of 0 degree.
c) Carbon fiber + epoxy:
Unidirectional carbon fiber + Epoxy Resin + Epoxy
Hardener Ratio of 2 : 1 respectively
No of layers: 7 for 3 mm thickness.
Layers arranged in Matrix form.
If 1st layer is 90 degree, next layer of 0 degree.
Above composition of materials used for experimental testings.
Microstructure is small scale structure of materials. Its strongly influences the physical properties of such as strength, toughness, hardness etc.

Fig. 20 - Testing specimens and microstructure of carbon fiber material

Fig. 21 - Testing specimens and microstructure of Jute 50% E glass fiber material

Fig. 22 - Testing specimens and microstructure of of Polyester and Continuous Roving Laminate 70% E glass fiber material

B) Tensile strength:
It's a capacity of material withstand load tending to elongate. For testing we use UTM machine. A universal testing machine is used to test the tensile stress and compressive strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. For test we used ASTM D 638-2003 standard.

Fig. 23 - Tensile test report of carbon fiber material

Fig. 24 - Tensile test report of Jute 50% E glass fiber material
From Fig. 23, 24 and 25 shows the tensile strength report of respective materials. For the testing we take 100 mm gauge length specimens. Table 2 results shows basis on respective specimen quality.

**Table 2**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Tensile strength(Mpa)</th>
<th>Displacement (mm)</th>
<th>Stress (Mpa)</th>
<th>strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel</td>
<td>215</td>
<td>0.05</td>
<td>1400</td>
<td>0.016</td>
</tr>
<tr>
<td>2</td>
<td>E-Glass+Polyester</td>
<td>210.66</td>
<td>0.16</td>
<td>1323</td>
<td>0.0063</td>
</tr>
<tr>
<td>3</td>
<td>E-Glass + Jute</td>
<td>131.47</td>
<td>1.028</td>
<td>1882</td>
<td>0.040</td>
</tr>
<tr>
<td>4</td>
<td>Carbon Fiber</td>
<td>187.92</td>
<td>1.268</td>
<td>3508</td>
<td>0.0499</td>
</tr>
</tbody>
</table>

**C) Impact test:**

Impact test used for evaluate the toughness and notch sensitivity of material. For test we used IZOD Impact test.

A pivoting arm is raised to a specific height then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity.

**Table 3**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Izod Impact Strength in KJ/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>E-Glass+Polyester</td>
<td>397.55</td>
</tr>
<tr>
<td>3</td>
<td>E-Glass + Jute</td>
<td>121.92</td>
</tr>
<tr>
<td>4</td>
<td>Carbon Fiber + Epoxy</td>
<td>164.06</td>
</tr>
</tbody>
</table>

**D) Hardness test:**

Indentation hardness tests are used in mechanical engineering to determine the hardness of a material to deformation. Several such tests exist, wherein the examined material is indented until an impression is formed; these tests can be performed on a macroscopic or microscopic scale.

**Table 4**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Specimen</th>
<th>Rockwell Hardness R scale (60Kg Load,1/2” Ø Ball)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steel</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>E-Glass+Polyester</td>
<td>102</td>
</tr>
<tr>
<td>3</td>
<td>E-Glass + Jute</td>
<td>76</td>
</tr>
<tr>
<td>4</td>
<td>Carbon Fiber</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 2, 3 and 4 shows experimental testing results. Polyester and Continuous Roving Laminate 70% E glass fiber material can withstand in front of steel. It can be replacement of steel in chain.
VII. CONCLUSION

A) FEA :

Table 1 shows stress, strain, displacement analysis of different hybrid composite materials. From the results Polyester and Continuous Roving Laminate 70% E glass fiber material can satisfy the requirement of materials. Carbon fiber goes near to satisfactory conditions but not satisfy. 50% jute glass fiber failed in analysis.

B) Experimental testing :

In experimental testing we carried out stress, strain, displacement, tensile strength, hardness test and impact test of hybrid composite materials to compare its physical properties with SS304 material. From the table 2,3 and 4 we shows that Polyester and Continuous Roving Laminate 70% E glass fiber material meet values of physical properties of steel.

In future this composite material can replace steel in chain linkage.

REFERENCES


