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To compare the strength of metal fiber rope and natural fiber rope using FEM

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Abstract

Fiber ropes are improved in strength throughout time to the point that they are beginning to replace wire ropes in certain applications. Fiber ropes are risen in durability. The development of high-tensile fibres and developments in fibre rope structures have been key contributions. It began with high-strength nylon and polyester fibre ropes, ropes made of both of those fibres, polyester and polypropylene ropes, as well as polypropylene and polyethylene ropes. As a consequence, stronger and stronger ropes can be manufactured, with a fibre strength component providing a “10-to-one strength-to-weight ratio” advantage over wire rope as the final outcome. Wire rope made from steel, jute fibre, and Kans fibre is subjected to FEM analysis in this work. When using the “ANSYS structural model simulation software”, findings are assessed in terms of equivalent stresses, maximum principal stresses (MPS), bending stresses (ETS), and equivalence strains (EQT) & total deformation. The study’s main goal is to determine how efficient natural fibres may be in substitute of steel as a wire rope.

Keywords: High tensile fibre; fiber ropes; FEM analysis; Equivalence strains; strength to weight ratio.

1. Introduction

Construction of important offshore materials and structures, including welded girder beams, tube columns, deck panels as well as finished jacket / module modules sometimes involves heavy lifting. “Offshore steel platforms” cannot be properly produced without massive lifting equipment.

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The elevators, lifting crane, suspension bridge, and mines hoisting all require wire ropes. Additionally, due to its low twist and torsional rigidity, the rope can be twisted more easily around a sheave or winding drum, simplifying the structures that the rope is used in. This is an advantage. Many wire ropes, such as hoisting ropes, are effective even when loaded with big objects. Any problem with the rope might have catastrophic implications, demonstrating the need of rope research.

1.1. Components of steel wire Rope

Because of the way its numerous components work together to achieve a similar purpose, a wire rope is frequently compared to a machine. If you want to make a simple rope, you just need three wires, but for most applications, you'll need far more complex ropes. Steel wire rope's constituent components may be seen in this cross-section.

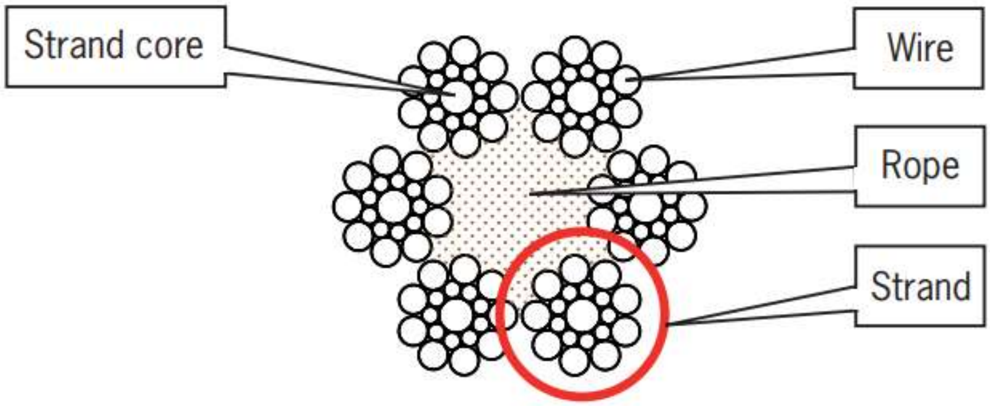

Figure 1: Cross section of a steel wire rope with the components of the rope clearly indicated

1.2. Composite Material

As the name suggests, composite materials combine the physical and chemical features of two distinct materials. You may develop materials that specialise in certain jobs by mixing and matching different types of carbon fibres. They're also good for increasing stiffness and strength. This is because they increase the qualities of their underlying materials and may be used in a wide range of settings, as opposed to standard materials.

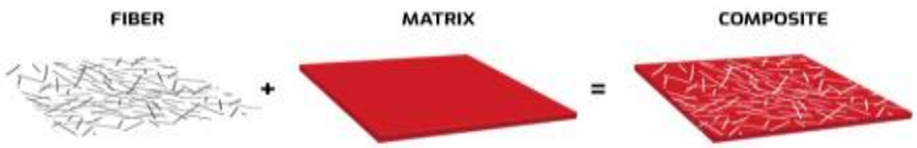

Figure 2: Composite material

1.3. Advantages of fiber over conventional materials

- A fiber core can be made of natural or synthetic polypropylene fibers. Fiber cores offer greater elasticity than a steel core.
- Fiber material is nonconductive.
- Fiber material provides better strength with less weight as compared to steel wire rope.
- Fiber wire rope is more flexible and durable.
- Fiber wire rope is less costly and easy to manufacture as compared to steel wire rope.

1.4. Objectives

- To study the behaviors of wire rope using FEM Analysis
- The conventional material will be replaced using natural fiber material.
- The result of conversional material and natural fiber will be brought under comparison.
- To apply different amount of load and to calculate the behavior.

2. LITERATURE REVIEW

Zhang, Zhang and Pan[1] "Magnetic flux leakage testing" has issues when trying to find flaws in wire rope. Excitation devices are bulky and cumbersome, and damage signals generally have a poor signal-to-noise ratio. These are the most evident drawbacks. The tiny detector proposed in this study is described in detail. A simple construction, ease of installation, low weight, and excellent mobility distinguish the presented device from existing detecting systems. The gadget is light and thin, weighing just 508 grams. The wires and strands on the wire rope's surface give it its unique appearance. Wire rope's distinctive helical structure generates a magnetic strand-waveform signal that has a higher amplitude than the defect signal.

Guerra-Fuentes et al.,[2] A catastrophic breakdown happened during execution after 53 days of service for a steel wire rope in a 12-ton overhead crane system. When the wire rope failed, it was dissected on both ends and examined for damage on both ends. "Visual examination, stereoscopic analysis, scanning electron microscopy, and micro hardness tests" have been used to investigate the cause of the failure. For the purpose of correlating operational circumstances with suspected failure reasons, data was gathered from spread sheets.

Ivanov et al.,[3] For example, pin sling behaviour when bent across small diameter rigid bodies was tested to identify the bending-induced loss in sling statistic strength. Papailiou's model was improved by including plasticity into the material behaviour and increasing the number of strands in the friction model from one to multiples of two. Additional research has showed that the diameter ratio isn't the only element that affects sling bending strength decrease; friction between wires as well as rope geometry, such as lay angle and number of wires, were also shown to be significant factors.

Liu, Zheng and Liu,[4] Depending on Love's thin rod theory, the impact of individual wire lay direction on the mechanical behaviour of multi-strand wire ropes under axial stress is being studied. We'll use a standard 7 x 7 wire rope with a separate rope core for this experiment. There are eight possible wire rope lay directions to examine, with a focus on the double helix wires' lay direction. The internal forces of the rope are calculated using two theoretical models: the hierarchical calculation approach and the direct calculation method. The “finite element analysis” of the “multi-strand rope” is used to evaluate the numerical findings based on the two models. As previously mentioned, the hierarchical computation approach yields result that are more closely aligned with those obtained using “finite element modelling (FEM)”.

Zhao et al., [5] A high sample size is necessary for wire rope fatigue life prediction, and there are a lot of unknowns. The study item for this work is a 40 6 31SW FC type wire rope. The fatigue life prediction of wire rope based on grey theory is accomplished under the situation of limited sample size fatigue life data. For starters, this research develops a better GM model and estimates the durability life facts of wire rope under small sample size conditions to address the issues with current fatigue life prediction. As a result, the reliability stress-life curve of the crucial rope sites is calculated by combining this data with the corresponding alternating stress applied to the important wire rope locations during a fatigue test.

Miao et al., [6] A technology for reinforcing stone slabs using pre-stressed near-surface mounted (NSM) steel wire ropes is presented to improve the flexural behaviour of stone building structures. Using the reinforcement ratio, pre-stress level, as well as bonding agent as measurement methods, six reinforced stone slabs were flexed under four-point bending. Furthermore, for the sake of comparison, a plain stone slab was included in the test procedure. A ductile failure mechanism with noticeable deflection was discovered via experimental examination on the enhanced stone slabs.

Battini et al., 2020 [7] For predicting metallic rope fatigue life, this research provides a thermal technique. Rope specimens are subjected to rotating bending fatigue tests, and also the temperature development of the ropes is tracked until the specimens fail. Using thermally dissipated energy and mechanical degradation as justification, the suggested technique is sound. To carry out experimental fatigue testing, the bending load and rotating speed are varied in various situations. A theoretical model based on temperature data allows for damage progression and rope life to be estimated based on experimental findings.

3. RESEARCH METHODOLOGY

3.1. Steps of Methodology

For analyzing stress and strain in wire rope, ANSYS software is used. And in ANSYS workbench, static structural model is selected which defines and calculate physical properties and stress, strain and deformation. For design of wire rope or jute rope, CATIA software is used because of its easy interface and easy process. The by importing the design into ANSYS model, process is followed by giving the materials which will be used in analysis. Then by applying boundary condition according to defined parameters and according to base paper, results are evaluated in form of equivalent stress, strain and total deformation. [8] [9] [10]

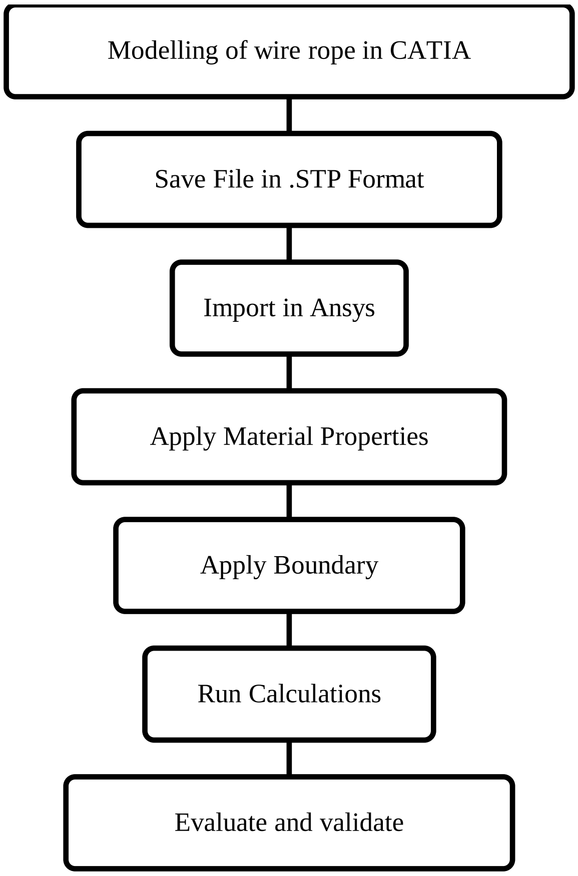

Figure 3: Working Methodology

4. Material property

The property of Stainless steel, Jute fiber, Kans fiber is determined with respect to their Young's modulus, density and Poisson's ratio and their separate values are listed in table below: [11] [12]

Table 1: Properties of stainless steel

Properties	**Value**
Young's modulus(GPa)	180
Density (Kg/m^3)	7850
Poisson's ratio	0.3

Table 2: Properties of Jute fiber

Properties	Value
Young's modulus(GPa)	20
Density (Kg/m^3)	1450
Poisson's ratio	0.38

Table 3: Properties of Kans fiber

Properties	Value
Young's modulus(GPa)	9.5
Density (Kg/m^3)	441
Poisson's ratio	0.33

5. RESULTS AND DISCUSSION

5.1. Comparative values in all materials

In below mentioned table, Maximum stress, stain and total deformation is defined and compared for all the cases. Which shows value of maximum stress is maximum in Jute fiber because of its mechanical properties and value of strain is maximum in Kans fiber. And in the total deformation case as well Kans fiber got the maximum deformation. And jute fiber got the maximum principal stress in comparison to other materials.

Table 4: Maximum value obtained of each parameter with each material with 2000 N

parameter	Stainless Steel	Jute fiber	Kans fiber
Stress(MPa)	2375.8	2568.7	2448.4
Strain	0.012637	0.12844	0.25772
Total Deformation(mm)	0.31073	2.9235	6.1514
Maximum principal stress(MPa)	3002.9	3582.6	3194.4
Shear stress(MPa)	297.81	389.76	331
Strain energy(mJ)	0.021481	0.20079	0.4253
$\boldsymbol{\sigma_T = \sigma(1+\varepsilon)}$	2405.822	2898.623	3078.12848
$\boldsymbol{\varepsilon_T = ln(1+\varepsilon)}$	0.0125578	0.120836	0.22887

Table 5: Maximum value obtained of each parameter with each material with 4000 N

Parameters	Stainless Steel	Jute fiber	Kans fiber
Stress(MPa)	4751.5	5137.5	4897.7
Strain	0.025274	0.25687	0.51545
Total Deformation(mm)	0.62146	5.847	12.303
Maximum principal stress(MPa)	6005.8	7165.1	6388.7
Shear stress(MPa)	595.61	779.52	661.99

Strain energy(mJ)	0.085926	0.80317	1.7012
$\sigma_T = \sigma(1+\varepsilon)$	4871.5894	6457.169	7421.97
$\varepsilon_T = ln(1+\varepsilon)$	0.02495	0.22862	0.4157

Table 6: Maximum value obtained of each parameter with each material with 6000 N

Parameters	Stainless Steel	Jute fiber	Kans fiber
Stress(MPa)	7127.3	7706.2	7345.1
Strain	0.037911	0.38531	0.77317
Total Deformation(mm)	0.9322	8.7704	18.454
Maximum principal stress(MPa)	9008.6	10748	9583.1
Shear stress(MPa)	893.42	1169.3	992.99
Strain energy(mJ)	0.19333	1.8071	3.8277
$\sigma_T = \sigma(1+\varepsilon)$	7397.503	10675.47	13024.11
$\varepsilon_T = ln(1+\varepsilon)$	0.03721	0.325923	0.572768

5.2. Comparison of stress

Equivalent stress comparison in all materials

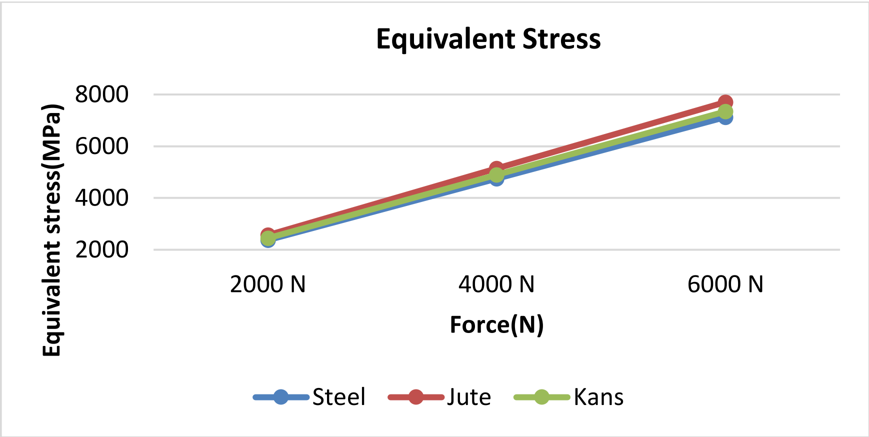

Figure 4: Equivalent stress with respect to force (N)

Maximum principal stress comparison in all materials

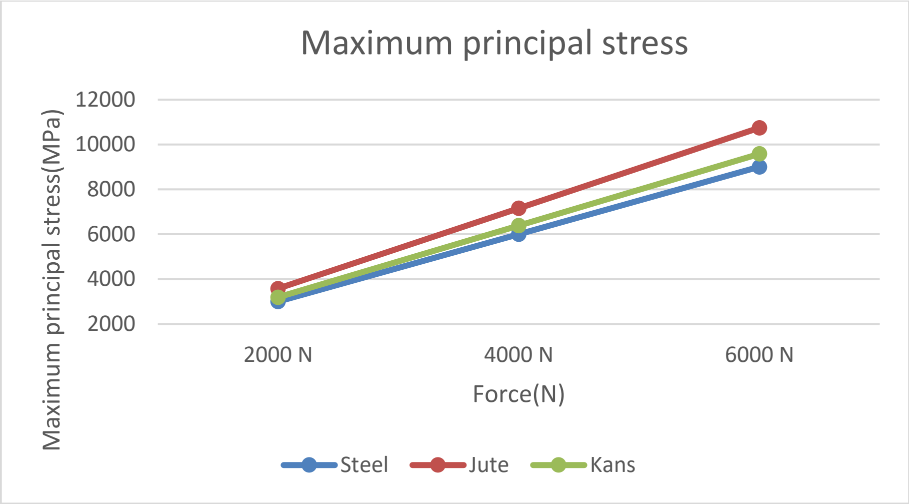

Figure 5: Maximum principal stress with respect to force (N)

Shear stress comparison in all materials

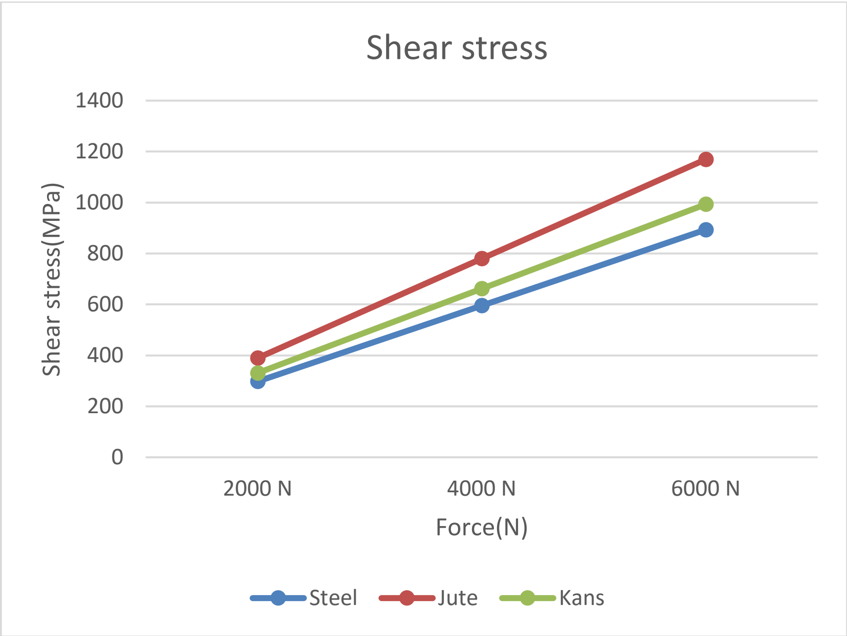

Figure 6: Shear stress with respect to force (N)

5.3. Comparison of Strain

Equivalent elastic strain comparison in all materials

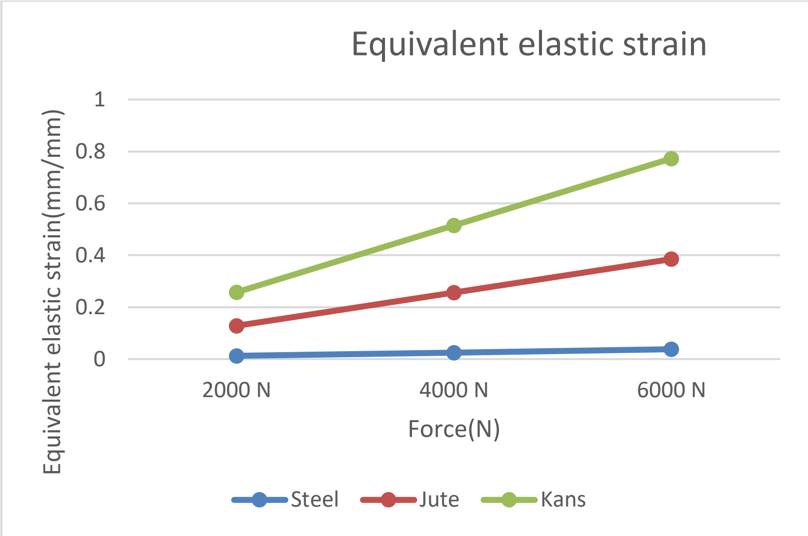

Figure 7: Equivalent elastic strain with respect to force (N)

Strain energy comparison in all materials

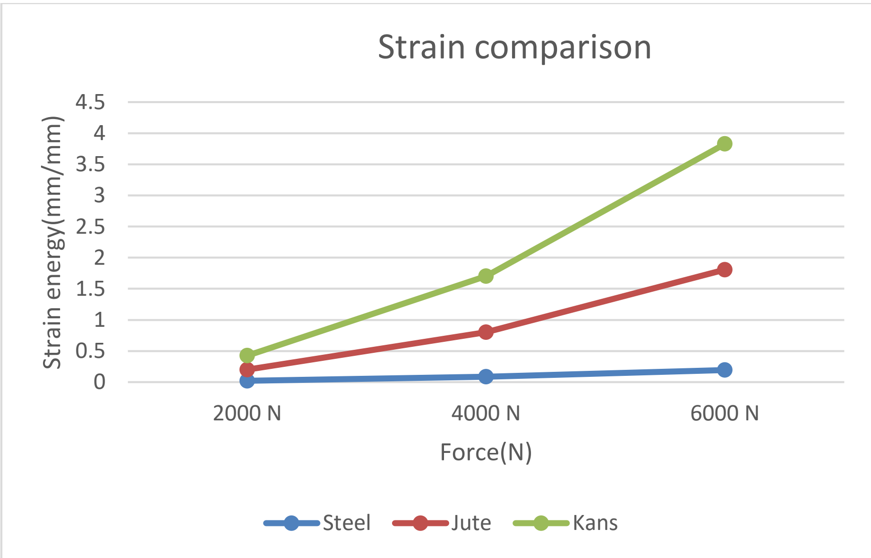

Figure 8: Strain energy with respect to force (N)

5.4. Comparison of total deformation

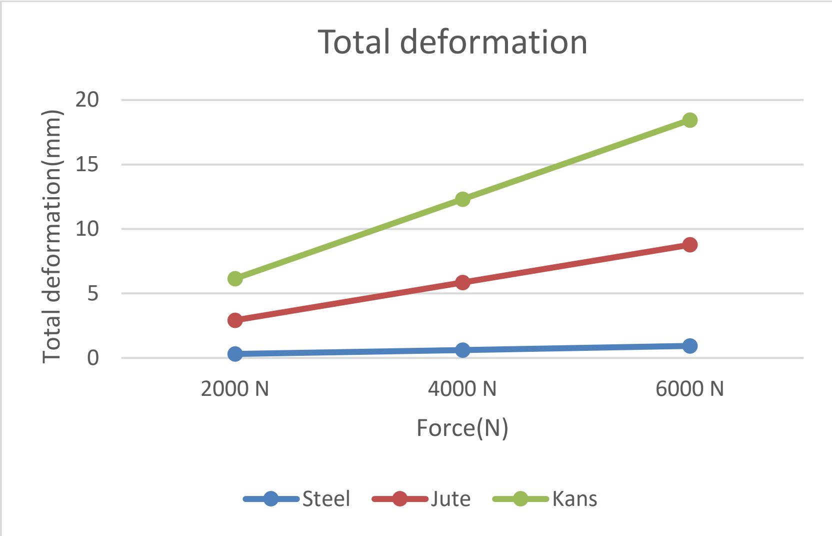

Figure 9: Total deformation with respect to force (N)

6. CONCLUSION

In this study, stress and stain analysis is performed to find out the better material for wire rope material which can bare same strength with more easy way. And for that steel is replaced with naturally available fiber which is jute fiber and Kans fiber. And they are analysed with same boundary condition and with same load applied which were applied on steel wire rope. Values of stress is found maximum by using jute fiber whereas value of total deformation is found maximum by using Kans fiber. As per the results it can be calculated that natural fibers like jute fiber, Kans fiber can be a good replacement for steel ropes because natural fiber also fulfilling the required strength of the wire rope. And according to the comparison of results it can be concluded that kans fiber is a better replacement of steel as it provides better results as compare to jute fiber.

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