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MODELLING AND ANALYSIS OF HELICAL ROPEWAY STRING

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Abstract

A ropeway is a type of maritime lifting gadget used to move light stores and hardware across waterways or gorges. It includes a jackstay, threw between two sheers or gyns, one at either end, from which is suspended a square and tackle, that is allowed to go along the rope and pulled to and fro by inhauls (ropes connected to the pulley from which the square and tackle are suspended). It is a valuable strategy for transportation for an extremely short separation.

In this paper here helical ropeways string were developed by using sold works and then analyzing with static and dynamic boundary conditions, here to suggest optimum materials for optimum ropeway string 4 materials were chosen (SAE 304, SAE416, steel 440c, S45c) to analyses them, by knowing each material results, in this process helical ropeway string were analyzed with each material comparing with each other material results, and then combining all material together to attach each string, and calculated results, finally paper conclude by showing suitable tables and graphs, with optimum material to increase the durability of the object.

Keywords: ropeway, pulley, inhauls

1. Introduction:

A ropeway is a type of maritime lifting gadget used to move light stores and hardware across streams or gorges. It contains a jackstay, threw between two sheers or gyns, one at either end, from which is suspended a square and tackle, that is allowed to go along the rope and pulled to and fro by inhauls (ropes connected to the pulley from which the square and tackle are suspended). It is a helpful strategy for transportation for an exceptionally short separation. In the start of the twentieth century the ascent of the white collar class and the recreation business took into account interest in touring machines. Before 1893 a joined products and traveler conveying cableway was introduced at Gibraltar. At first its travelers were military work force.

Regardless of the presentation of different security measures (back-up power generators, clearing plans, and so on.) there have been a few genuine occurrences on aeronautical tramways.

The main aim is to design and optimizing the helical string ropeway by utilizing computer aided tool solid works, and then analyzing ropeway strings with transient and dynamic boundary conditions and then calculating results of ropes with different materials. In this process first 4 materials were chosen which are similar in their physical properties but different in their yield limit values, those 4 materials are (SAE 304, SAE416, steel 440c, S45c). the reason behind choosing these materials, all these materials are having better yield strength values compare to mild steel material, so that by replacing these materials with regular mild steel material the strength and durability of the rope string can increases without effecting other properties.

2. Problem Formulations

2.1 Ropeway with arbitrary loads

The ropeway mainly includes working cables, brackets, trolleys and tractor. Working cables includes bearing cable and traction cable. The bearing cable is the important part of ropeway, which bears the loads of trolleys and cargos. The traction cable is a closed rope and driven by the tractor to move along the bearing cable in the ropeway. The single-span circulating ropeway is shown in Figure 1. The span between brackets is Ls, and altitude difference is $h_{s.}$

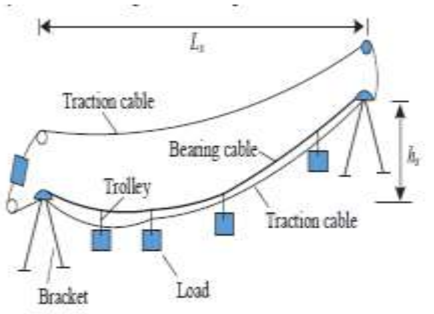


Figure 1 Single-span circulating ropeway

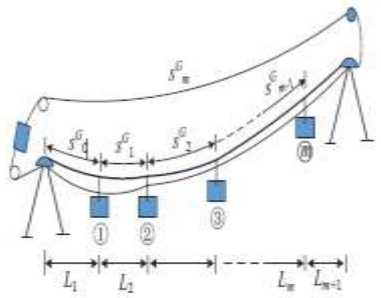


Figure 2 Loads parameters

There are *m* loads on the ropeway with the weights G_i (i=1… m) respectively. The lengths of traction cable between loads are $S^G{}_i$ (i=1… m-1), which are kept constant during movement. The length of traction cable from the tractor to the first load is defined as $S^G{}_0$ and the length between the last load and tractor is defined as S^{Gm}, shown as Figure 2.

2.2 Analysis of bearing cable and traction cable

The equal span and altitude difference of bearing cable and traction cable as shown in Figure 2, the points A and B coincide in every section of bearing cable and traction cable that means the span and altitude difference of every section are equal. So the 2(m+1) equations below are obtained:

$$L_i^l - L_i^t = 0 \quad (i=1,\ldots, m+1)$$
$$h_i^l - h_i^t = 0$$

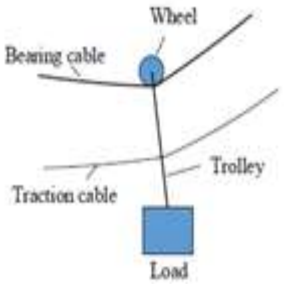
Constant of the total span and altitude difference

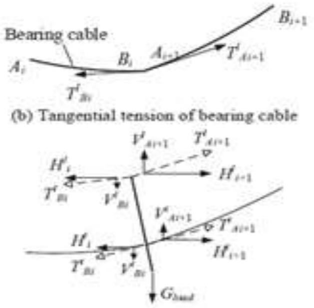
$$\sum_{j=1}^{m+1} L_j^t - L_s = 0$$
$$\sum_{j=1}^{m+1} h_j^t - h_s = 0$$

For return traction cable, the equations are obtained as

$$L_{m+2}^t - L_s = 0$$
$$h_{m+2}^t - h_s = 0$$

Tension balance of bearing cable and traction cable beside load





(a) Connect of bearing cable of traction cable *(b) force analysis of trolley*

Figure 3 Force analysis of bearing cable and traction cable beside load

The bearing cable and traction cable are connected by the loads, shown as Figure 3(a). The number of cables beside load is i, i+1 respectively. The wheel of trolley rolls on the bearing cable and makes cable bent down. Therefore, the tangential tensions of bearing cable beside load are equal, shown as Figure 3(b). So there are m equations of tension balance:

$$T^t_{Bi} - T^t_{Ai+1} = 0\ (i=1,\dots,m)$$

The Force analysis of trolley is shown in Figure 3(c), the 2m tension balance equations in the horizontal and vertical directions can be obtained

$$\begin{matrix} H^t_{i+1} - H^t_i + H^t_{i+1} - H^t_i = 0 \\ V^t_{Ai+1} - V^t_{Bi} + V^t_{Ai+1} - V^t_{Bi} - G_i = 0 \end{matrix}\ (i=1,\dots,m)$$

3. Materials & Methodology

3.1 Materials:

Table 1:

Materials	Steel 304	Steel 416	Steel - 440C	S45C
Young's Modulus	1.9*10^11 Pa	1.997*10^11 Pa	1.997*10^11 Pa	1.987*10^11 Pa
Poison ratio	0.29	0.289	0.228	0.298
Density	7700 Kg/m^3	7800 Kg/m^3	7800 Kg/m^3	7870 Kg/m^3
Yield Strength	300 MPa	650 MPa	450 MPa	710 MPa

3.2 Methodology:

Solid works process: Here helical rope string length consider to be as 1.5meters, it means 1500mm, and to create helical rope string here sweep option were used, diameter of helical string was considered as 5mm and total number of strings was 7.

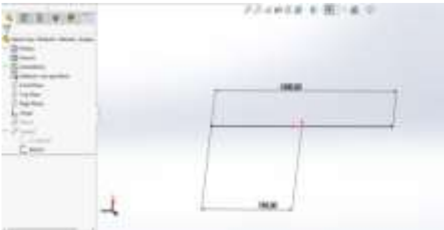


Figure 4a Taking length of the string

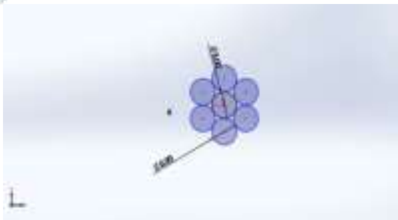


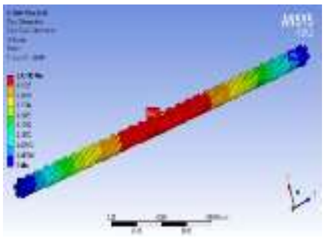
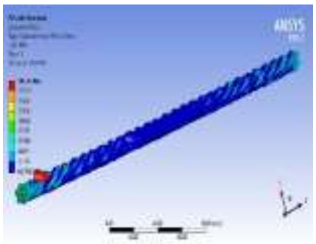
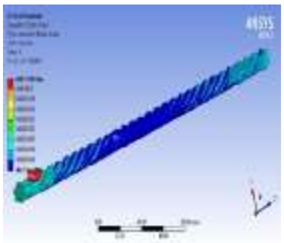
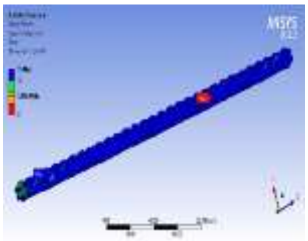
Figure 4b Taking diameter of the string

After completing selecting sweep option now use twisted no of turns enter 5. And then enter ok, above image shows the final model of helical rope string

Figure 5 Twisting the string

4. ANSYS Process

After completing design in solid works now the final model were imported into Ansys workbench and the model is showing in

			
Deformation	Stress	Strain	Safety Factor

below image, to import into Ansys workbench here the object should be in either IGES or step file format only,

4.1 Meshing and Boundary Conditions

To calculate the results here need to apply boundary conditions on it, before applying boundary conditions first of there should be a contact between each string so that the load will transfer from one end to other end, this meshing will create intersections and cross connection in between them so that by that contact the load can transfer throughout the object.

Figure 6A Meshing of the string

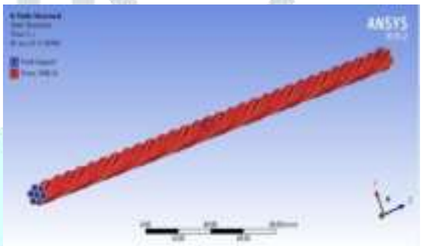
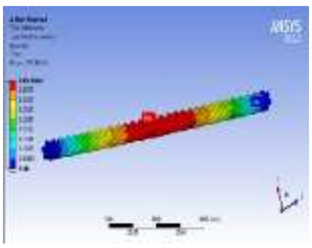
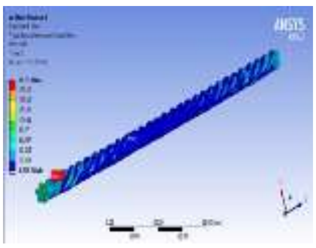
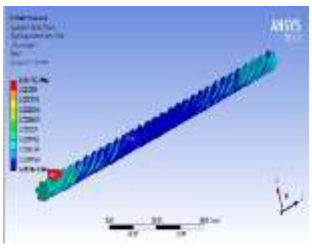
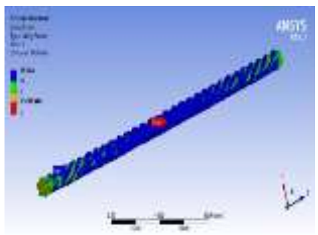


Figure 6B Boundary conditions of the string

Here force is consider to as boundary condition on it and here Fixing both ends by using fixed support option then after apply Force 3540N apply then solve the results of deformation, stress, strain, safety factor, this 3540N is maximum limit to apply on helical string, at this loading the safety factor is nearby 1.5 only, so that it is consider to be maximum allowable load on this circular string without any breakage on it,

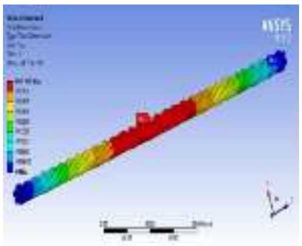
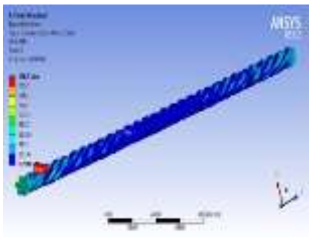
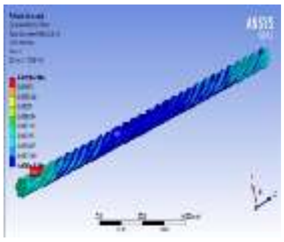
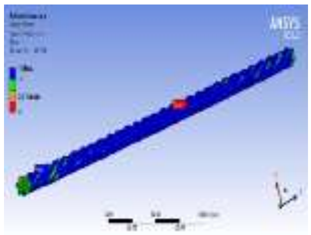
4.2 Static analysis of string

Material SAE 304

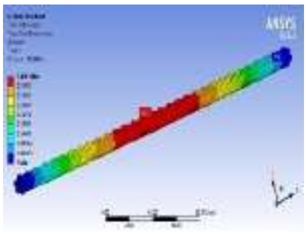
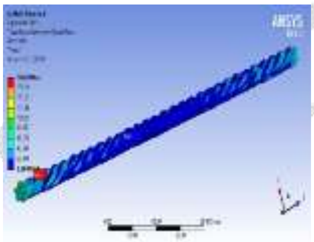
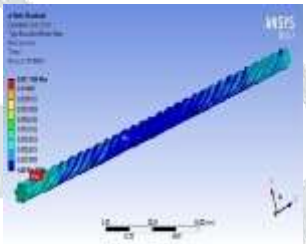
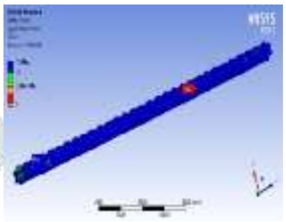
			
Deformation	Stress	Strain	Safety Factor

Material SAE 416

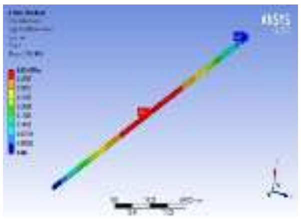
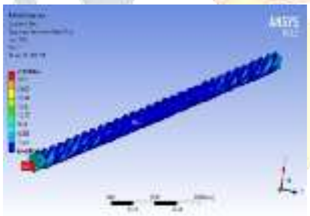
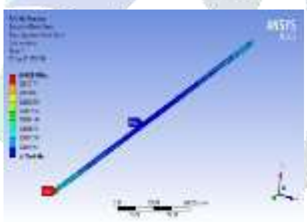
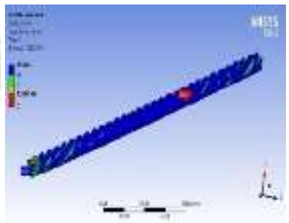
Material Steel 440C

 Deformation	 Stress	 Strain	 Safety Factor

S45c

 Deformation	 Stress	 Strain	 Safety Factor

Combining all materials

 Deformation	 Stress	 Strain	 Safety Factor

Tables 2: Results of Static analysis of string

	SAE 304	SAE 416	Steel 440C	S45C	Combination of all 4 materials
Deformation mm	0.45433	0.43115	0.41774	0.4363	0.43747
Stress MPa	197.13	197.17	198.2	196.99	277.93
Strain	0.0012323	0.0011711	0.0011842	0.0011768	0.0013918
Safety Factor	1.5218	3.2967	2.2704	3.6043	1.6191

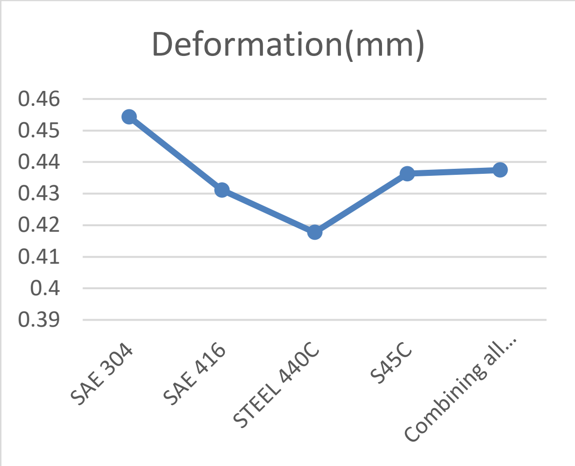


Figure Deformation

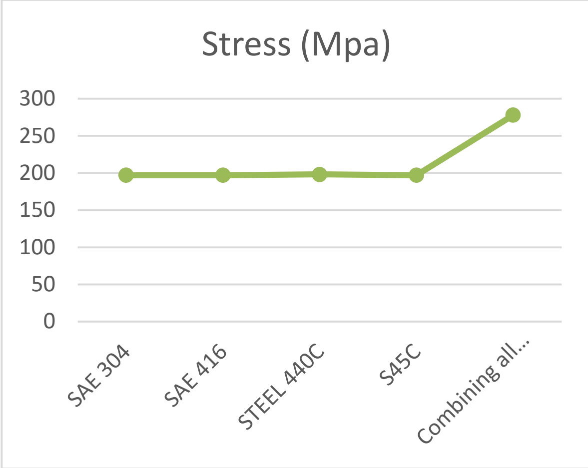
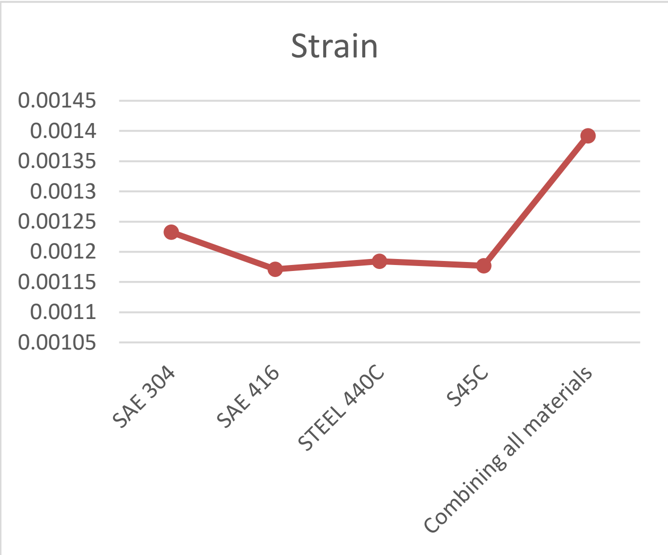


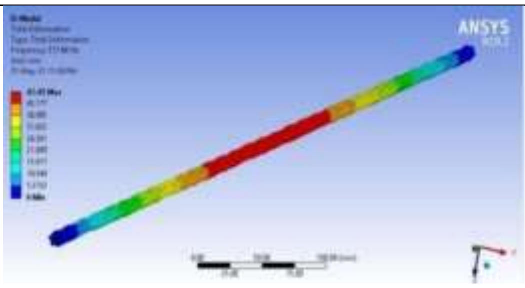
Figure Stress

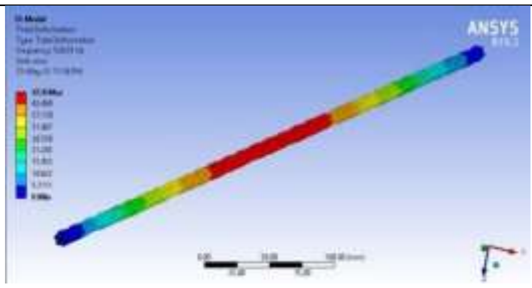


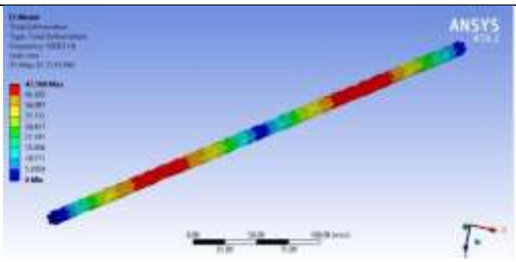
4.3 Natural Frequency

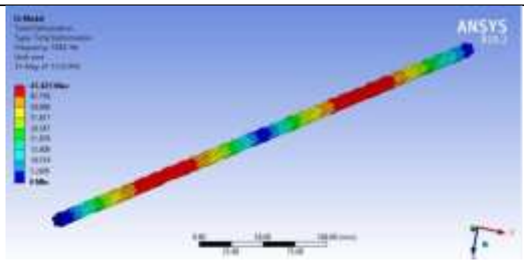
The natural frequency is the frequency at which a system oscillates when it is disturbed. If you pluck a guitar string in the middle it vibrates back and forth. If you pluck the same string 10 times in a row and measure the frequency of vibration you find that it is always the same. When plucked, the string vibrates at its natural frequency. The pendulum also had a natural frequency. The natural frequency is important for many reasons

4.3.1 Natural frequency & Mode Shapes









Tables 3: Natural Frequencies of string

Material	SAE 304	SAE 416	STEEL 440C	S45C	Combining All Material
Mode1 (Hz)	517.46	527.77	536.12	522.32	530.85
Mode2 (Hz)	524.55	535	543.51	529.46	538.6
Mode3 (Hz)	1020.2	1040.5	1057	1029.7	1049.5
Mode4 (Hz)	1034	1054.6	1071.4	1043.7	1061.4

4.4 Harmonic analysis

Harmonic analysis is a branch of mathematics concerned with the representation of functions or signals as the superposition of basic waves, and the study of and generalization of the notions of Fourier series and Fourier transforms (i.e. an extended form of Fourier analysis). In the past two centuries, it has become a vast subject with applications in areas as diverse as number theory, representation theory, signal processing, quantum mechanics, tidal analysis and neuroscience.

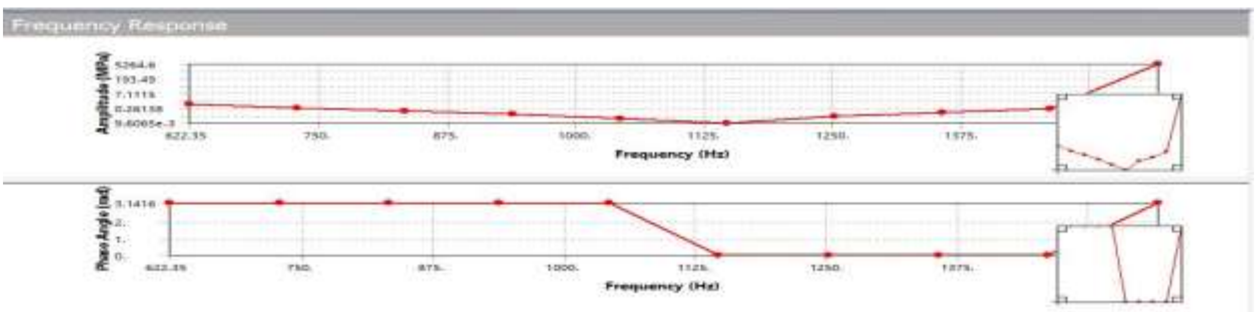
The term "harmonics" originated as the Ancient Greek word harmonikos, meaning "skilled in music". In physical Eigen problems, it began to mean waves whose frequencies are integer multiples of one another, as are the frequencies of the harmonics of music notes, but the term have been generalized beyond its original meaning.

The classical Fourier transform on Rn is still an area of ongoing research, particularly concerning Fourier transformation on more general objects such as tempered distributions. For instance, if we impose some requirements on a distribution f, we can attempt to translate these requirements in terms of the Fourier transform of f. The Paley–Wiener theorem is an example of this. The Paley–Wiener theorem immediately implies that if f is a nonzero distribution of compact support (these include functions of compact support), then its Fourier transform is never compactly supported (i.e. if a signal is limited in one domain, it is unlimited in the other). This is a very elementary form of an uncertainty principle in a harmonic-analysis setting.

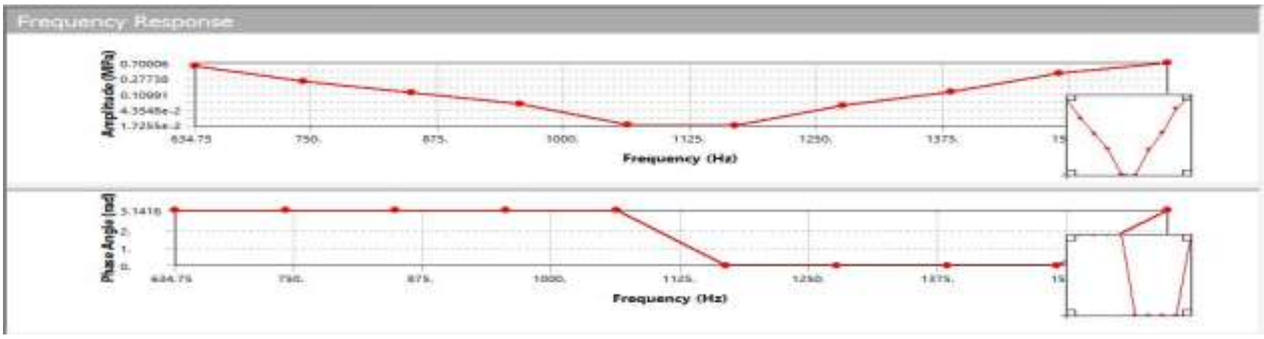
Fourier series can be conveniently studied in the context of Hilbert spaces, which provides a connection between harmonic analysis and functional analysis. There are four versions of the Fourier Transform, dependent on the spaces that are mapped by the transformation (discrete/periodic-discrete/periodic: Digital Fourier Transform, continuous/periodic-discrete/a periodic: Fourier analysis, discrete/a periodic-continuous/periodic

4.4.1 Harmonic analysis results

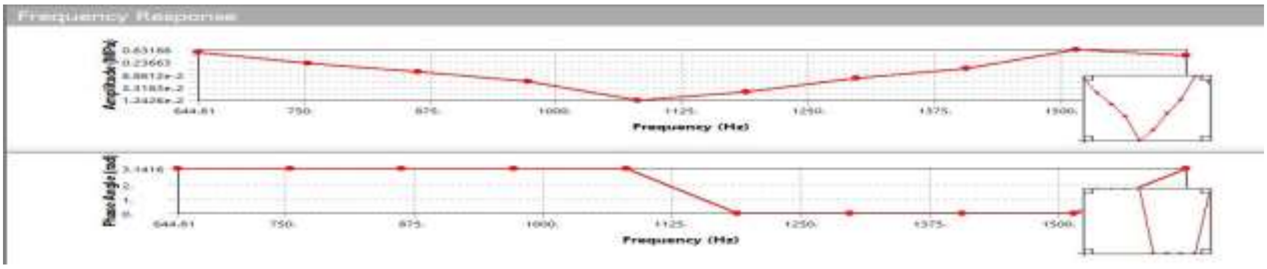
SAE 304

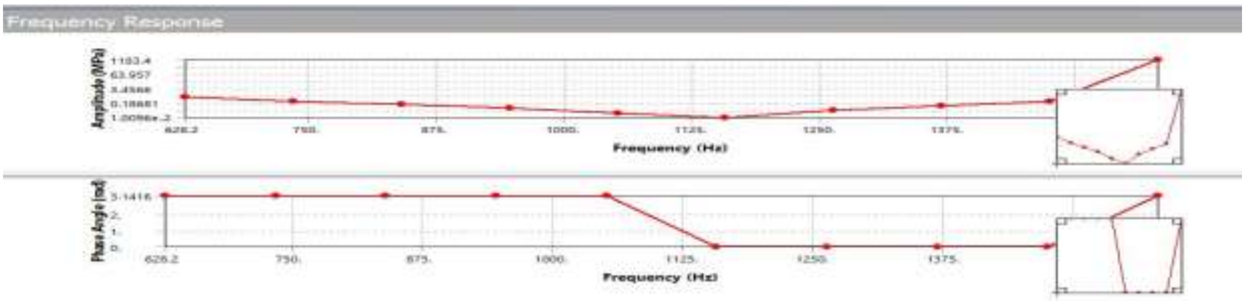


SAE 416



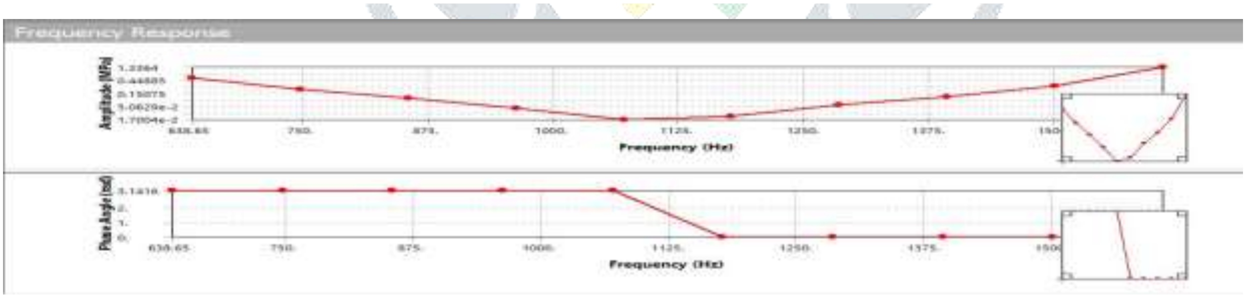
STEEL 440C





S45C

Combining All Material



Conclusion

In this thesis here helical ropeways string were developed by using sold works and then analyzing with static and dynamic boundary conditions, here to suggest optimum materials for optimum ropeway string 4 materials were chosen (SAE 304, SAE416, steel 440c, s45c) to analyses them, by knowing each material results, in this process helical ropeway string were analyzed with each material comparing with each other material results, and then combining all material together to attach each string, and calculated results,

From static analysis results, SAE 304 material can withstand maximum amount of force on it 3540N, at this load, here minimum safety factor value is near to 1.5. So that this value is maximum load which is SAE 304 material rope string can withstand. After completing this s45c material has highest amount of safety factor values among all, and then SAE 416 material has 2nd highest safety factor value, then steel 440c material has 3rd highest value. When combining all materials each other, here we observe that it is generating high amount of stress values compare to single material, so that this combination not suggested to use.

After completing static analysis results here dynamic analysis results also calculated, from this dynamic analysis results here it is observe that, s45c has 3rd highest frequency range, it means this material has highest static analysis stability but medium range vibrational stability values, whereas steel 416 material has highest frequency range values, and this steel 416 material is satisfying both static and dynamic stability conditions, and this can with stand more force and vibrations on it, compare to other materials. While combining all materials here we got better frequency results than any other material, but while choosing a better material or combination, it should be good at both static and dynamic loading conditions, so that's the reason these combination all materials are not suggested to do use, even though it has high vibrational frequency range values,

Finally thesis concludes SAE 416 material to increase the durability of the object.

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