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Design and Analysis of Micro Vertical Axis Wind Savonius Turbine

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ABSTRACT:
In this thesis, an advanced hybrid savonius and arm gear based structure will be designed and Modelled in 3D modelling software Creo 2.0. Static, Modal and Random Vibration analyses are being done on the structure to determine displacements, stresses, frequencies, shear stresses. Analysis are done for different materials Steel, Aluminium alloy, Titanium Alloy and Nickel alloy and compared for better material for the structure.

1.1 Introduction of Savonius Turbine:
In simplest turbines the Savonius turbine is one of them. Aerodynamically, it's a drag-type device, consisting of 2 or 3 scoops. Looking down on the rotor from on top of, a 2 scoop machine would seem like "S" form in cross section. Due to the curvature, the scoops expertise less drag when moving against the wind than when moving with the wind. The differential drag causes the Savoniusturbine to spin. As a result of their drag-type devices, Savonius turbines extract abundant less of the wind's power than alternative similarly-sized lift-type turbines[1]. Abundant of the area of the sweptback of a Savoniusturbine could also be close to the bottom, if its atiny low mount while not an extended post, creating the general energy extraction less effective owing to the lower wind speeds found at lower heights.

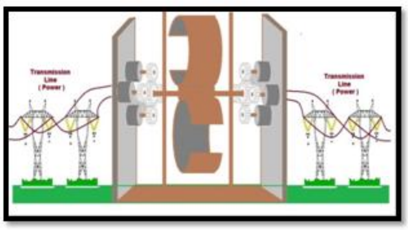

Fig 1.2: Main Savonius Assembly

1.2 Working Principle:
This experiment uses main arm having massive diameter with some thickness. This main arm is link with the savonius unit, meaning in keeping with the rotation of savonius unit, the main arm rotates. The main arm is smallest in size that of savonius unit. The main arm having major gear/wheel whose rev are going to be bigger than that of savonius unit meaning for single rotation of savonius unit the main arm rotates multiple times[2]. This advantage that is beneficial to extend the rev of main arm consequently sub arm, viasavonius unit.

Fig 1.3: Gear Mechanism (Main arm)

LITERATURE REVIEW
2.1 The work done by V.K.Kamble
This paper provides a good summary of the present standing and future development of wind power. As per the technical evolution and technical trends thought therefore we've got created an "Advanced Hybrid Savonius and arm gear primarily based effective Mechanical Structure for Multi-Station Optimized Power Generation[3].

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The advancement of this turbine is that, this turbine not solely rotates over multiple natural resources and artificial resources however additionally having capability of resources settlement into it per multiple savonius blade structure.

2.2 The work done by Prof. Kishor N. Wagh:

Increasing demand in energy expedited the necessity of fresh energy like wind energy. This study was done to research the look and development of a small Vertical Axis turbine (VAWT) Savonious kind. In regions wherever wind speed is proscribed Horizontal Axis Wind Turbines (HAWT) doesn't have a usage owing to current of air speed demand. VAWT offer operational skills at lower speeds associated don't need an alignment mechanism. Today, the foremost usually used turbine is that the Horizontal Axis turbine (HAWT), wherever the axis of rotation is parallel to the bottom. However, there exist alternative sorts of wind turbines, one in all which can be the first focus of this paper, the Vertical Axis turbine (VAWT)[4]. These devices will operate in flows returning from any direction, and take up a lot of less space than a conventional HAWT and VAWT are undoubtedly a reputable supply of energy for the long run. This Advanced Hybrid Savonious Multi-Station Structure unit uses four units i.e. Advanced Savonius unit, Main larger Arm, Sub 8 Arms, Multiple Generators Units therefore ultimately created Multi-station Structure. This Multi-Station Structure is that the demand of developing technology.

2.5 The work done by Fewderikus Wenehenubun:

He found the relationships between wind speeds and tip speed ratio or actual torsion that shows that the 3 blades turbine model has the very best tip speed ratio. Generally the 3 turbine models have important tip speed ratio at lower wind speed and a lot of stable at wind speed of seven m/s[5]. It implies that the turbine models has optimum move speed at the wind speed on top of seven m/s. 3 blades turbine model has the very best tip speed ratio at 0.555 with the wind speed of seven m/s.

This experiment provides the link between the particular torques of the shaft of turbine models for various wind speed. Four blades turbine model has higher torsion than that 2 or 3 blades turbine. Turbine model with four blades has a lot of drag force at any position once the wind rotor is in move position. Turbine rotor with a lot of variety of blades can deliver higher torsion for the shaft of the turbine. Variety of blades connected with the solidity of turbine, higher solidity can provide additionally higher torsion for the turbine[6].

3.2 MODELING AND ANALYSIS:

The modeling and analysis for this project is based on the journal paper “An Experimental Study of Advance Hybrid SavoniusWith Arm Gear Based Structure For Electric Power Generation by Vijay K.Kamble, Prof. Kishor N. Wagh, International Journal of Scientific and Research Publications, Volume 6, Issue 7, July 2016, 436 ISSN 2250-3153”[7].

3 D Model of Savonious Gear Turbine Assembly is Modelled in Creo 2.0.

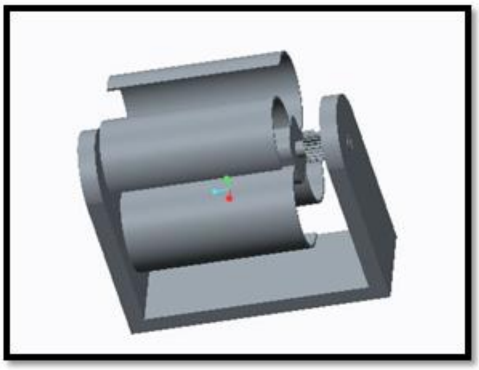

Fig 3.6: Assembly of Savonious gear turbine

3.3 Boundary Conditions

For Structural analysis rotational velocity value is taken from

ANALYSIS OF ADVANCED HYBRID SAVONIUS AND ARM GEAR BASED STRUCTURE FOR ELECTRIC POWER by V.K.Kamble

Rotational velocity: 30rpm

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4.4 Nickel Alloy

Static Structural Analysis

Static Structural Analysis of Present Savonious Turbine is done in Ansys Workbench 14.5

All the necessary data for conducting the analysis like material properties, geometry is provided into the system in static structural window.

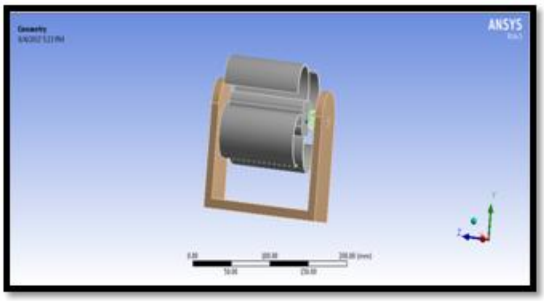

Fig 4.2: Imported model from Creo 2.0

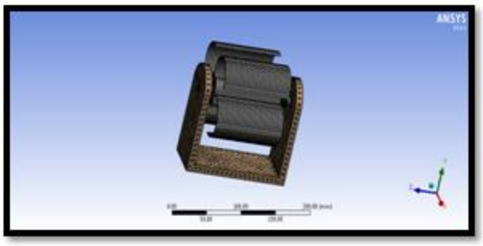

Fig 4.3: Meshed Model

The imported model has been meshed and the base of the assembly has been fixed for applying rotational velocities in clock wise direction.

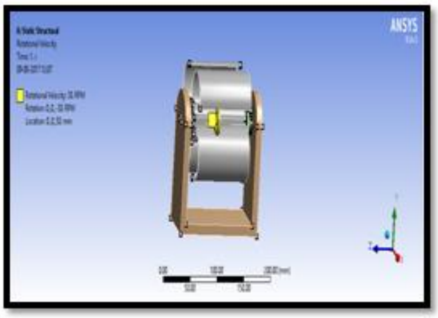

Fig 4.4: Rotational velocity applied on the blades

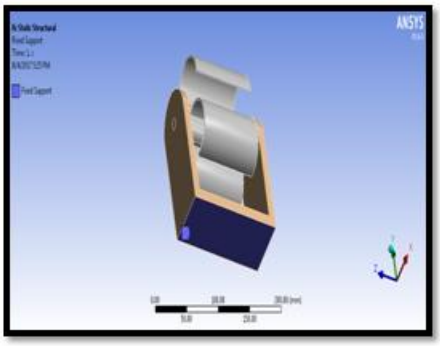

Fig 4.5: Fixed support is applied at bottom of the stand

4.4.1 Rotational Velocity - 30RPM:

The analysis is done for 30 RPM and the results are plotted in the graph, the red portion shown in the assembly picture shows the maximum Deformation and the dark blue portion shown in the picture shows minimum Deformation[8].

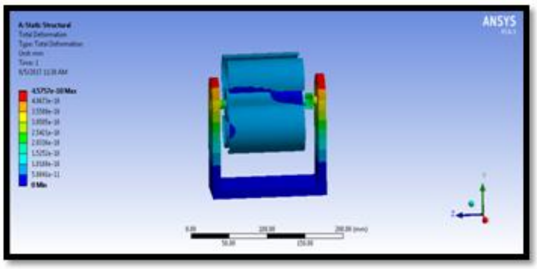

Fig 4.33: Total Deformational30rpm for Nickel alloy

The analysis is done for 30 RPM and the results are plotted in the graph, the red portion shown in the assembly picture shows the maximum Equivalent Stress and the dark blue portion shown in the picture shows minimum Equivalent Stress.

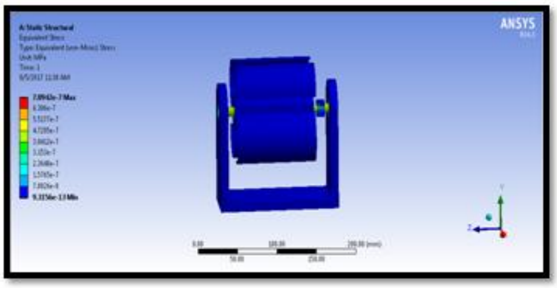

Fig 4.34: Equivalent Stress at 30rpmfor Nickel alloy

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The analysis is done for 30 RPM and the results are plotted in the graph, the red portion shown in the assembly picture shows the maximum Equivalent Elastic Strain and the dark blue portion shown in the picture shows minimum Equivalent Elastic Strain.

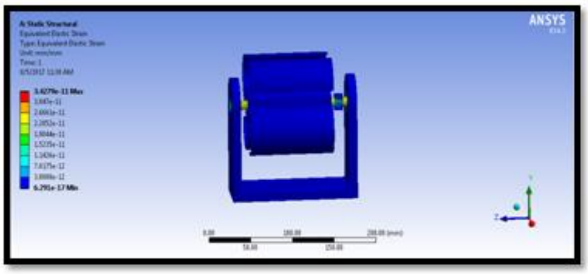

Fig 4.35: Equivalent Elastic Strain at 30rpm for Nickel alloy

5.4 Modal Analysis:

Modal analysis is done for testing the savories turbine under vibrational excitation

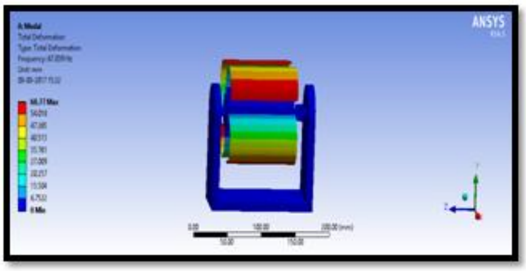

Fig 5.13: Mode -1for Nickel alloy

The modal analysis for frequency 67.839 Hz is done and the results for deformation has been plotted in the above pic with total maximum and total minimum deformation as 60.77mm and 0mm respectively, the maximum deformation is seen at the tips of the blades[9].

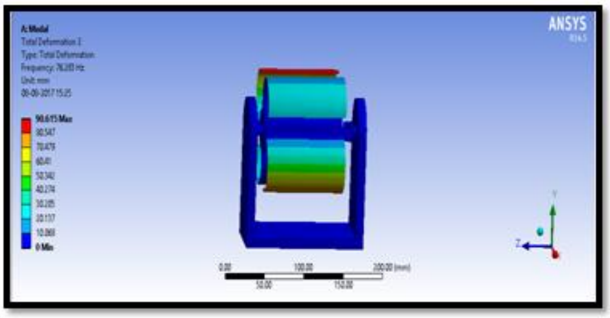

Fig 5.14: Mode -2 for Nickel alloy

The modal analysis for frequency 76.283 Hz is done and the results for deformation has been plotted in the above pic with total maximum and total minimum deformation as 90.615mm and 0mm respectively, the maximum deformation is seen at the tips of the blades.

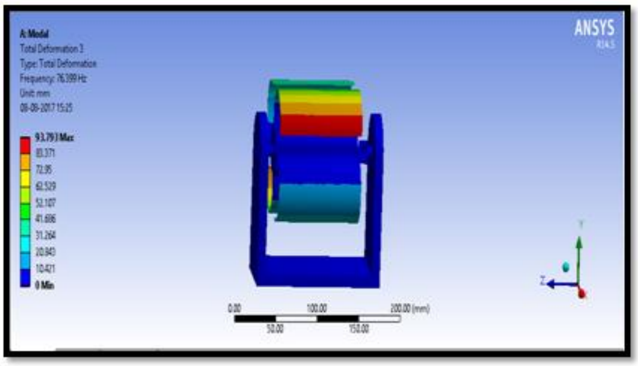

Fig 5.15: Mode -3 for Nickel alloy

The modal analysis for frequency 76.399 Hz is done and the results for deformation has been plotted in the above pic with total maximum and total minimum deformation as 93.793mm and 0mm respectively, the maximum deformation is seen at the tips of the blades[10].

6.1 RANDOM VIBRATION ANALYSIS:

The frequency results from the modal analysis are taken as inputs for Random Vibration analysis.
Select random vibration>analysis setting>right click>PSD displacement
Select >psd displacement >frequency

6.4 Nickel Alloy

Frequency(HZ)	Displacement(mm/HZ)
67.839	60.77
76.283	90.615
76.399	93.793

The data like Frequency and Displacement from previous analysis is noted in the above table.

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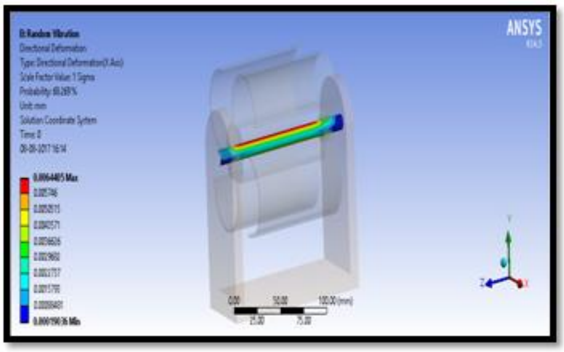


Fig 6.12: Directional Deformation for Nickel alloy

The results for the directional deformation is plotted the maximum deformation is shown in red color and minimum deformation is shown in blue color.

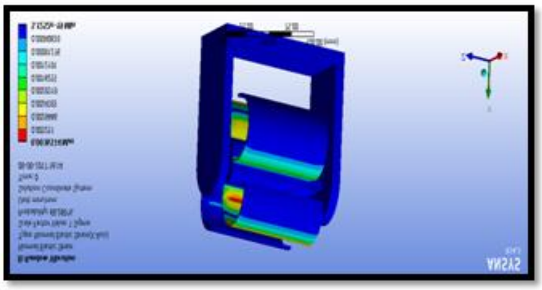


Fig6.13: Normal Elastic Strain for Nickel alloy

The results are plotted and it can be seen that normal elastic strain concentration is higher in places where red color is shown.

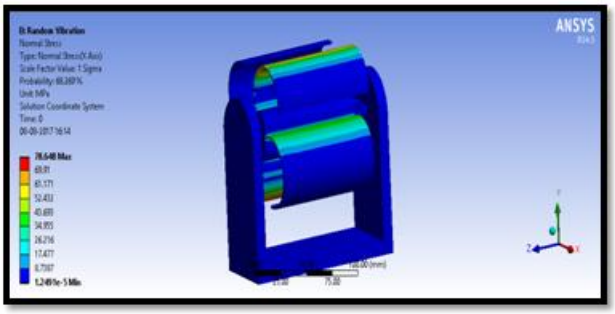


Fig 6.14: Normal Stress for Nickel alloy

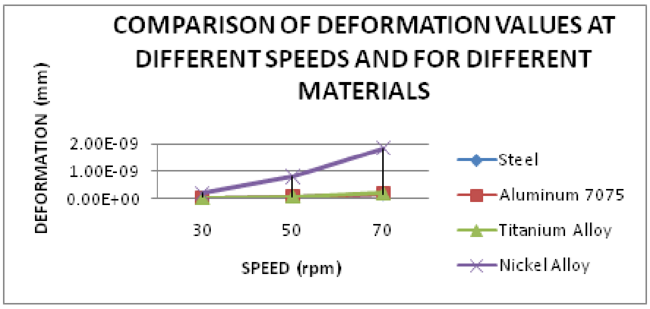
The maximum normal stress obtained is 78.648 Mpa whereas minimum normal stress obtained is 1.2491e^-5 Mpa.

RESULTS AND GRAPHS

7.1 Static Structural Analysis

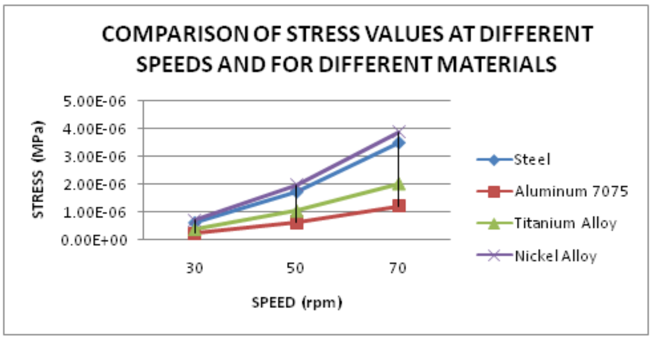
RPM	MATERIALS	DEFORMATION(mm)	STRAIN	STRESS(MPa)
30	Steel alloy	3.9319E-11	3.0979E-12	6.1946E-7
	Aluminum7075	4.5463E-11	3.0878E-12	2.2134E-7
	Titanium alloy	4.9566E-11	3.3664E-12	3.7021E-7
	Nickel alloy	4.5757E-10	3.4279E-11	7.0942E-7
50	Steel alloy	1.0922E-10	8.6051E-12	1.7207E-6
	Aluminum 7075	1.2628E-10	8.5771E-12	6.1483E-7
	Titanium alloy	1.3768E-10	9.3511E-12	1.0284E-6
	Nickel alloy	1.271E-9	9.5219E-11	1.9706E-6
70	Steel alloy	2.211E-10	1.7421E-11	3.4835E-6
	Aluminum7075	2.4751E-10	1.6811E-11	1.2051E-6
	Titanium alloy	2.6985E-10	1.8328E-11	2.0156E-6
	Nickel alloy	2.4912E-9	1.8663E-10	3.8624E-6

Graph is plotted for comparison of deformation and stress at different speeds for different materials



Graph 7.1 Comparisons of Deformation Values at Different Speeds for Different Materials.

In the above graph it can be seen that Nickel alloy has maximum deformation (Lower is better) at various RPM.



Graph 7.2 Comparisons of Stress Values at Different Speeds for Different Materials

In the above graph it can be seen that Aluminum has least stress of all the selected materials.

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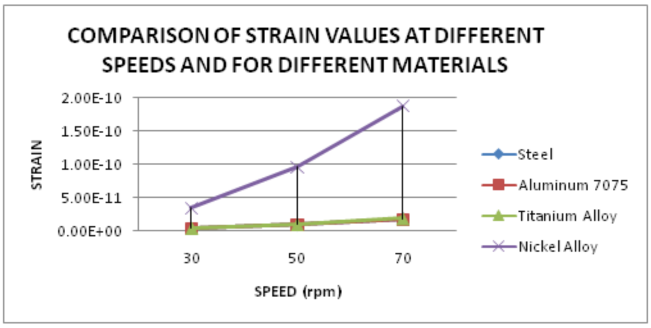
Graph is plotted for comparison of strain values at different speeds for different materials



Graph 7.3 Comparisons of Strain Values at Different Speeds for Different Materials

It can be observed that Nickel alloy has maximum strain (Lower is better) at various RPM when compared to other materials just like deformation Vs Speed Graph.

7.2 Modal Analysis:

	DEFORMATION (mm)		
MATERIALS	MODE1	MODE 2	MODE 3
STEEL ALLOY	65.501	97.411	100.99
AL7075	107.17	160.7	165.75
TITANIUM ALLOY	82.868	124.25	128.16
NICKEL ALLOY	60.77	90.615	93.793
	FREQUENCY (Hz)		
MATERIALS	MODE1	MODE 2	MODE 3
STEEL ALLOY	226.59	254.38	254.76
ALUMINUM 6061	224.11	252.86	253.26
TITANIUM ALLOY	214.63	242.17	242.55
NICKEL ALLOY	67.839	76.283	76.399

7.3 Random Vibration Analysis

MATERIALS	DIRECTIONAL DEFORMATION (mm)	NORMAL ELASTIC STRAIN	NORMAL STRESS (MPa)
STEEL ALLOY	0.011866	0.0068475	1421.1
AL7075	0.016509	0.0095054	678.29
TITANIUM ALLOY	0.014219	0.0081752	894.99
NICKEL ALLOY	0.0064405	0.0036574	78.648

CONCLUSION:

By observing static structural analysis results, the deformations, stresses are increasing by increasing the speeds. The stress values are less for Aluminum alloy 7075 when compared with other materials. The stress values are decreasing for Aluminum alloy 7075 by 64% when compared with that of Steel, by 24% when compared with that of Titanium alloy and by 68% when compared with that of Nickel alloy.

By observing modal analysis results, the deformations and frequencies are more for Aluminum alloy 7075 than other materials and less for Nickel alloy. This is due to the fact than Aluminum alloy 7075 is lighter than other materials. The frequency values are decreasing for Nickel alloy by 70% when compared with that of Steel, by 68.5% when compared with that of Titanium alloy and by 70% when compared with that of Aluminum alloy 7075.By observing Random Vibration analysis results, the deformations and normal stresses are more for Aluminum alloy 7075 than other materials and less for Nickel alloy. The deformations and stresses are increasing by increasing the frequencies. The normal stress values are decreasing for Nickel alloy by 94.4% when compared with that of Steel, by 91.2% when compared with that of Titanium alloy and by 88.4% when compared with that of Aluminum alloy 7075.By observing the above three analysis results we conclude that nickel alloy get the optimal parameters when compared with other materials.

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