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Modification and structural analysis of kinematic cage wheel to reduce stress and improve the F. O. S

Pothuraju Sumalatha and R Srinivasulu

Abstract
Agro-Technology is the process of applying the technology, revolution occurring in daily life and applying that to the agriculture sector which improves the efficiency of the crop produced and also to develop a better mechanical machine to help the agriculture field which reduces the amount and time of work spent on crop. Hence in this work of project we decided to design a better mechanical apparatus which is helpful for the farmers. This project consists of the better and modified design of the machine which can be used specifically for rice, wheat. Developed agriculture requirements to find new ways to improve efficiency. One approach is to utilize available information in the form of sophisticated machines for more effective usage of power than in the past. We can now move towards a new generation of equipment. The advent of autonomous system architecture gives us the opportunity to develop a Complete new range of agricultural equipment based that can do the right thing, in the right place, at the right time in the right way. The present study deals with the new design for cage wheels. In present study the structural conventional cage wheel is replaced by a newly Designed Cage Wheel having a double piston single cylinder mechanism. But its dimensions, specifications are made by Adhore to the dimensions of conventional cage wheel. This project describes composition and analysis of our newly designed cage wheel mechanism. The dimensions of an existing customary cage wheels and Mahindra 475 are taken for reference and evaluation of results. The scientific analysis is carried via finite element analysis using SolidWorks software. Stresses, deflection and strain energy results for both conventional and designed cage wheels were obtained. Result shows that, the designed cage wheels have competent strength to withstand fluctuating loads. Unlike conventional cage wheels, it is intact to travel with, even on high ways.

Keywords: Modification and structural, kinematic cage, reduce stress, F. O. S

Introduction
Agriculture is a demanding sector of the Indian economy. In India around 70% of the population earns its livelihood from agriculture. It still sustained livelihood to the people in our country. It accomplishes the basic need of human beings and animals. It is a vital source of raw material for many Agro based industries. India's geographical status is matchless for agriculture because it provides many agreeable conditions. There are plain areas, fertile soil, long growing season and wide variation in climatic condition etc. Apart from unique geographical conditions, India has been consistently making cutting-edge efforts by using science and technology to increase yielding India has three distinct agricultural/cropping seasons. You might have heard about *kharif*, *rabi* and *zaid*. In India there are specific crops grown in these three seasons. For example rice is a *kharif* crop whereas wheat is a *rabi* crop.

- India has an agriculture-based economy
- 43% of India's territory remains employed in agricultural activities as against 11% in the world
- India has the potential to become the food supplier of the world. It has the cultivable land, all the seasons for production of all varieties of crops, fruits and vegetables, well developed agribusiness system that works in its own way.
- Agriculture is the back bone of Indian Economy

Half cage wheels

Fixed Tractor Cage Wheel is fastened temporarily to the pneumatic tires. It causes no damages to the roads. So no need to remove the cage wheels throughout its operation. But it's performance is not as much good as a Detachable Tractor Cage Wheel. Since it is a combination half of pneumatic tire and remaining is cage wheel, it can also be termed as Half cage wheel. 50% government subsidy is available for half Cage Wheel. Different models of half cage wheels handy in today's market are as given below.

Half Cage Wheels

Full conventional cage wheel

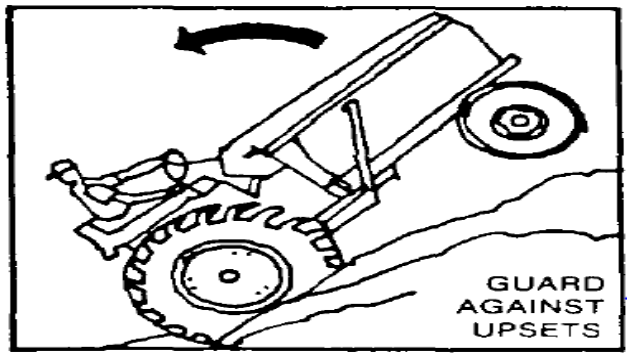
In Detachable Tractor Cage Wheel, fitting can be done simply with nut and bolts. It gives comparatively higher performance as compared to the half cage wheels. According to the essentials these cage wheels can be attached or detached very easily. So most of the farmers prefer this type of cage wheel. As it is fully consist of metallic structure it is also known as Full cage wheels.

Full Conventional Cage Wheel

Problems with conventional cage wheel

Generally different types of manufacturing companies produces different sizes of conventional cage wheels (also called as full cage wheels). It means that they are made without any particular design and have no standard dimensions. Due to which cage wheels are not giving much performance. Moreover, the conventional cage wheel has two adverse effects. They are,

- Upsets down (Revolt of tractor itself)
- Damages to Roads



Revolt of farm tractor as it stuck in the mud

To rectify these problems we have gone for design of kinematic cage wheel taking the full convectional cage wheel of MAHINDRA 475 as basis.

Dimensions of conventional full cage wheels

Inner wheel:	Outer wheels:
Ro= 56 cm	r_o=46 cm
Ri=51 cm	r_i=41 cm

Distance between inner and outer wheels=54 cm
Thickness of each ring=3 cm

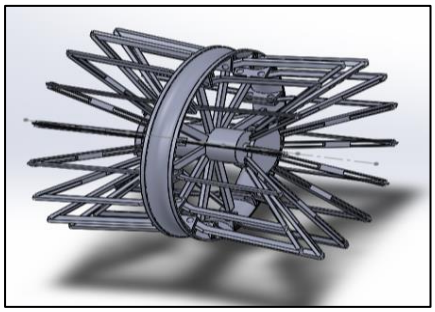
Number of links=15
Length of each link=55 cm

Attachable disc

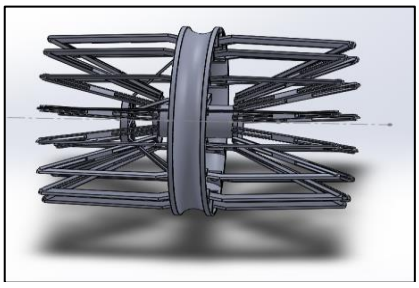
Do'=40cm	Di'=14cm
	t=5cm

This attachable disc is at a distance of 20 cm from inner wheel.

Assembly of essential parts



Wide open of arm links



Closed arm links

In this figure the arm links are made to open wide. With this configurtion of links, pulverisation of soil can be acieved.

Because in this case some of the arm links are continously in contact with the mud soil. Based on the type of soil, Nature of soil the links can be made wide to controll the depth of pulverisation.

Here the area of contact with the surface of mud soil is provisionally more, the chances of wheels going deeper into the ditches of mud soil is less. So is the reason why there is no mean of upsets down in this case. Further safety improvements such as using levelling blade at the rear side of the tractor. Its use damps the reaction torque developed during the operation in the fields.

In following figure the arm links are made to close. When the farm tractor comes on to the roads this arrangement is done. With this provision, only the Pneumatic tire touches the ground. So the road is much safer. It is found that the vehicle could move without any difficulty on the tar and cement roads.

Hydraulic fluid is forced into the cylinder, causing the links open wider. To bring the links back hydraulic fluid is reclaim. According to the requirements the links are made to open wide and bring back to the close position.

Drawback of the kinematic cage wheels

Analysis is done on the kinematic cage wheels. From that we found that the designed kinematic cage wheel have developed the stresses more than the yield stress and the factor of safety is less when compared to the conventional cage wheel. So it cannot withstand the loads.

Modification of kinematic cage wheel

The kinematic cage wheel in which the stresses developed are more is modified by changing the dimensions of the part in which the stresses are more.

The following part dimensions are modified

1. Arm link
2. Rim with attachable disk

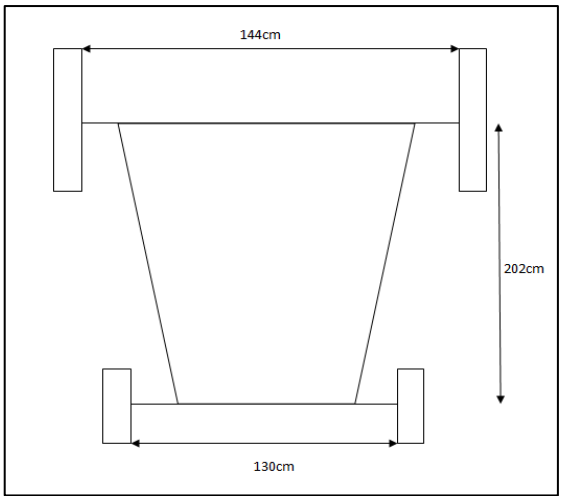
Analysis of cage wheels using solid works

All the analysis for the cage wheel is done by using SolidWorks 2013. SolidWorks acted as a platform to perform both modeling and analysis. The stress and deflection analysis is done for conventional, kinematic cage wheel, kinematic cage wheel and modified kinematic cage wheels using SolidWorks software. The results for the three is compared.

Calculations

For a tractor to stay erect, its CG must stay within the tractors stability baseline. Stability baselines are imaginary lines drawn between points where tractor tires contact the ground. The line connecting the rear tire contact points is the rear stability baseline, while the lines connecting the rear and front tires on the same side are the side stability baselines. Front stability baselines exist but have limited use in stability/instability considerations, and are not normally include in such discussions. See Figure 1 for a complete illustration of a tractors CG and stability baselines.

Total weight of the tractor is acted on the cage wheels as well as on front pneumatic tires. So, based on the position of centre of gravity, we can find out how much weight acts on each cage wheel. The central concept in tractor stability/instability is Center of Gravity (CG). A tractors CG is the point where all parts balance one another.. The top view of tractor is as shown in the figure. The outline of tractor is a trapezoid.



Based on the given dimensions location of centre of gravity can be found as below.

Centroid = (x, y)

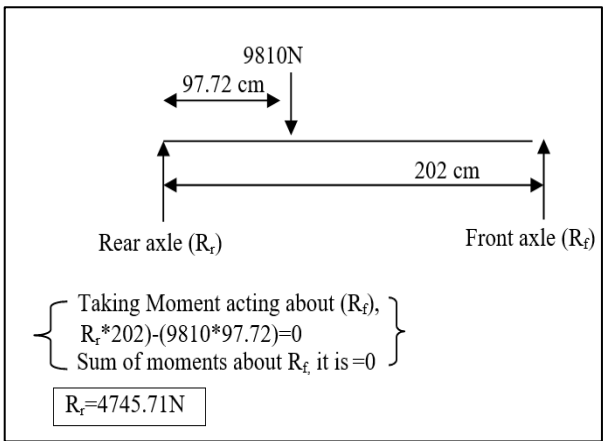
$$y = \frac{A_1Y_1+A_2Y_2}{A_1+A_2}$$

$$= \frac{[(130*202) * 101] + [(14*202) * (202/3)]}{(130*202) + (202*14)}$$

= 97.72 cm

So the Centre of gravity lies at 97.72 cm from the rear axle. Total weight of tractor is 2 tons, i.e. 19620N.But the load acting on half side becomes 9810N. Now, we are concerned to find the weight acting on each cage wheel.

We can assume it as a just supported beam.



So, each wheel experiences 4745.71 N

This results in approximately 30 percent of the tractor weight on the front axle, and 70 percent on the rear axle. Added weights also effect the CG.

Torque calculations: (On conventional cage wheel)

Driving torque helps the cage wheel to go forward, while

reaction torque acts on cage wheel itself, causing to reduce its fruition. The direction in which the reaction torque acts is exactly opposite to the direction of driving torque. We need to calculate that reaction torque.

The reaction torque can be calculated as follows,

Reaction torque=Frictional force*radius of central ring

But frictional force arose here is due to the weight acting on the cage wheels,

So reaction force R_n can be taken as the weight acting on the cage wheel.

i.e. R_n=4745.71 N

Frictional force $=\mu*R_n$

$= 0.3*4745.71$

$\{\mu= 0.3, R_n=4745.71 N\}$

$= 1423.713$ N

Reaction torque T = Frictional force* radius of central ring

$= 1423.713 *0.56$

$= 79.7279$ N-m

Reaction torque T = 79.7279 N-m

Torque calculations: (on our designed cage wheel)

No matter whatever may be the position of links i.e. whether the links are in fuully opened position or fully closed position, the torque acting remains same.

Reaction torque = 1423.713*0.58

= 82.575N-m

Now gathering all the data,

Torque values

1. on conventional cage wheel=79.7279 N-m
2. on designed cage wheel

- While the links are in fully closed position=82.575 N-m
- While the links are in fully open position=82.575 N-m

Based on these values further analysis can be done on designed and conventional cage wheels.

Analysis

Analysis part includes Studying material properties, Study properties. Applying pressure, meshing. Scruples of loads and torque, obtained from the calculation's part, are applied on the assembly of both the modellings. Same material is used for both the models.

Material properties

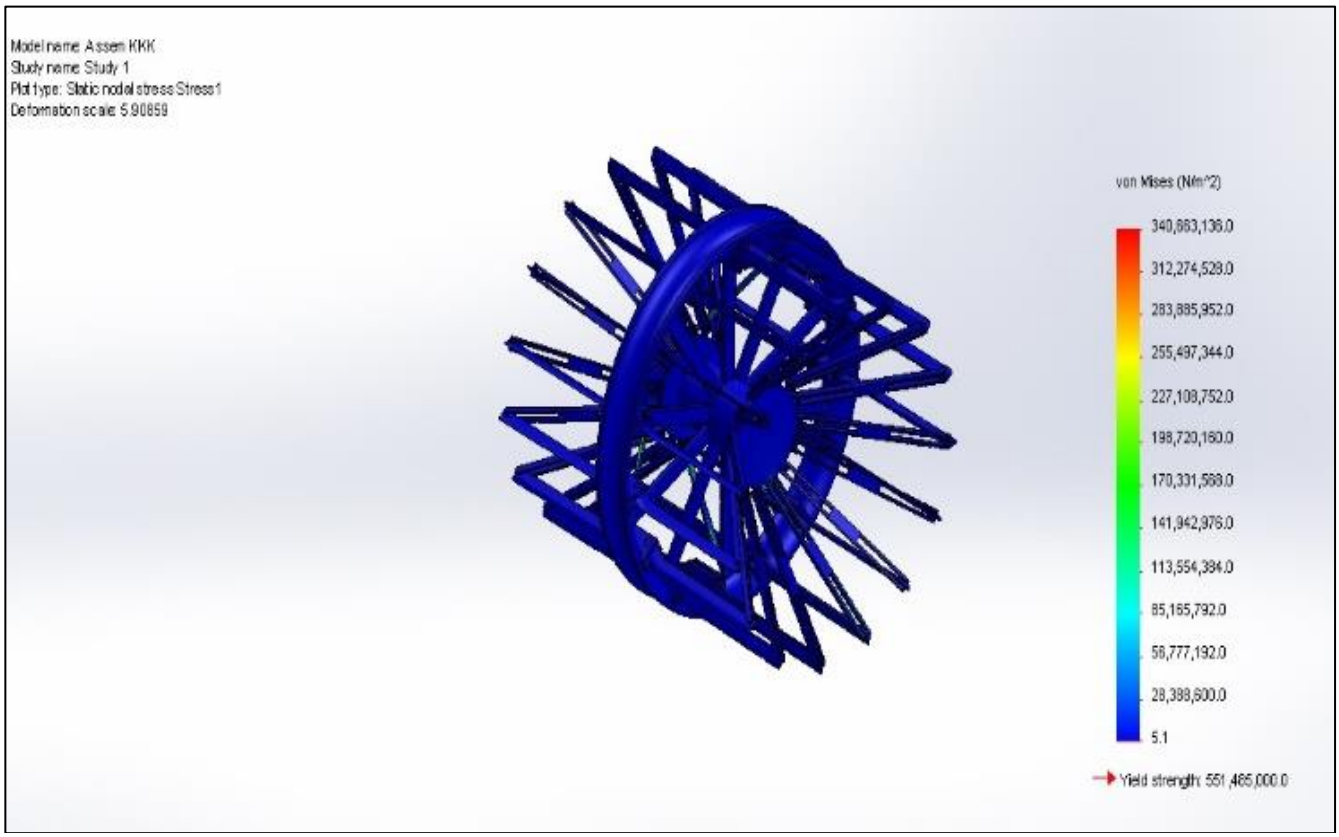
Units

On kinematic cage wheel

Study result for kinematic cage wheel

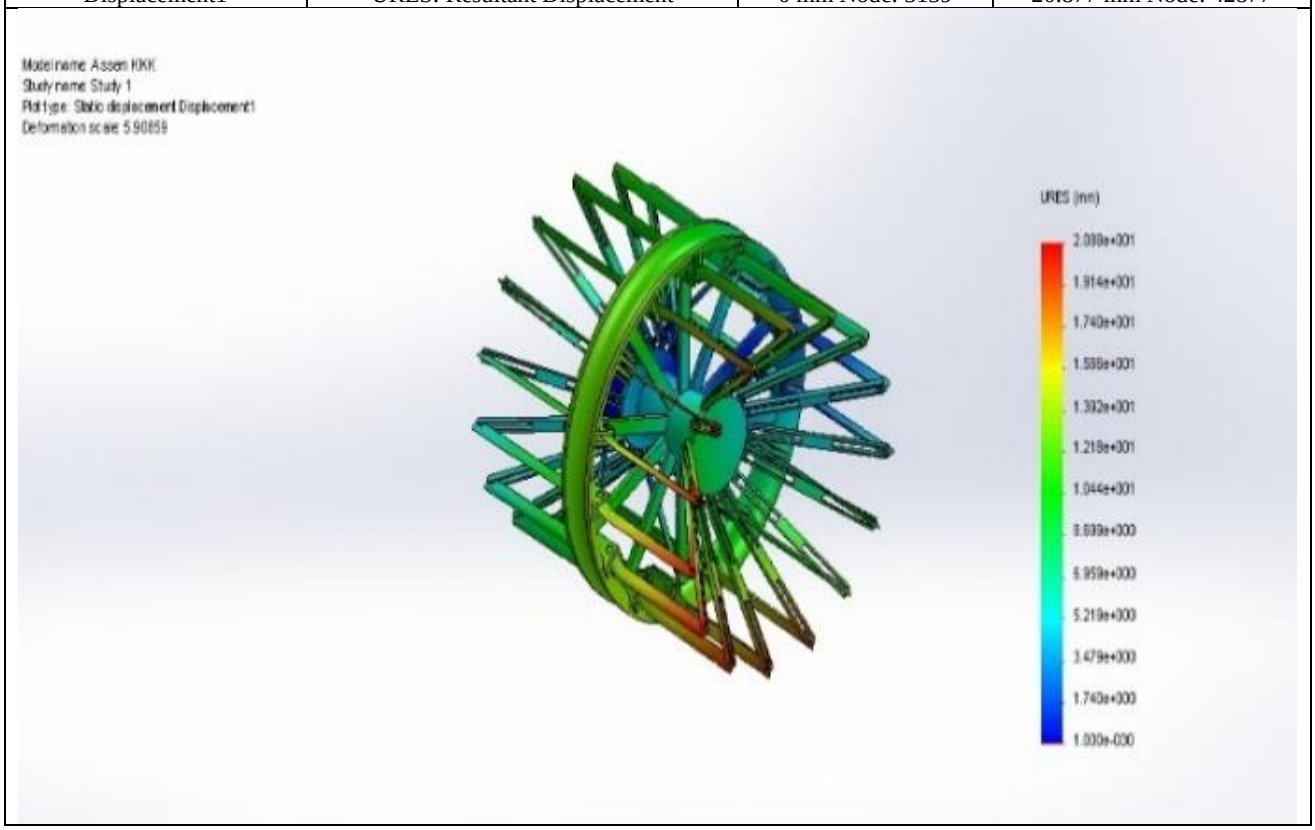
1. **When the links are open**

- **Stress**



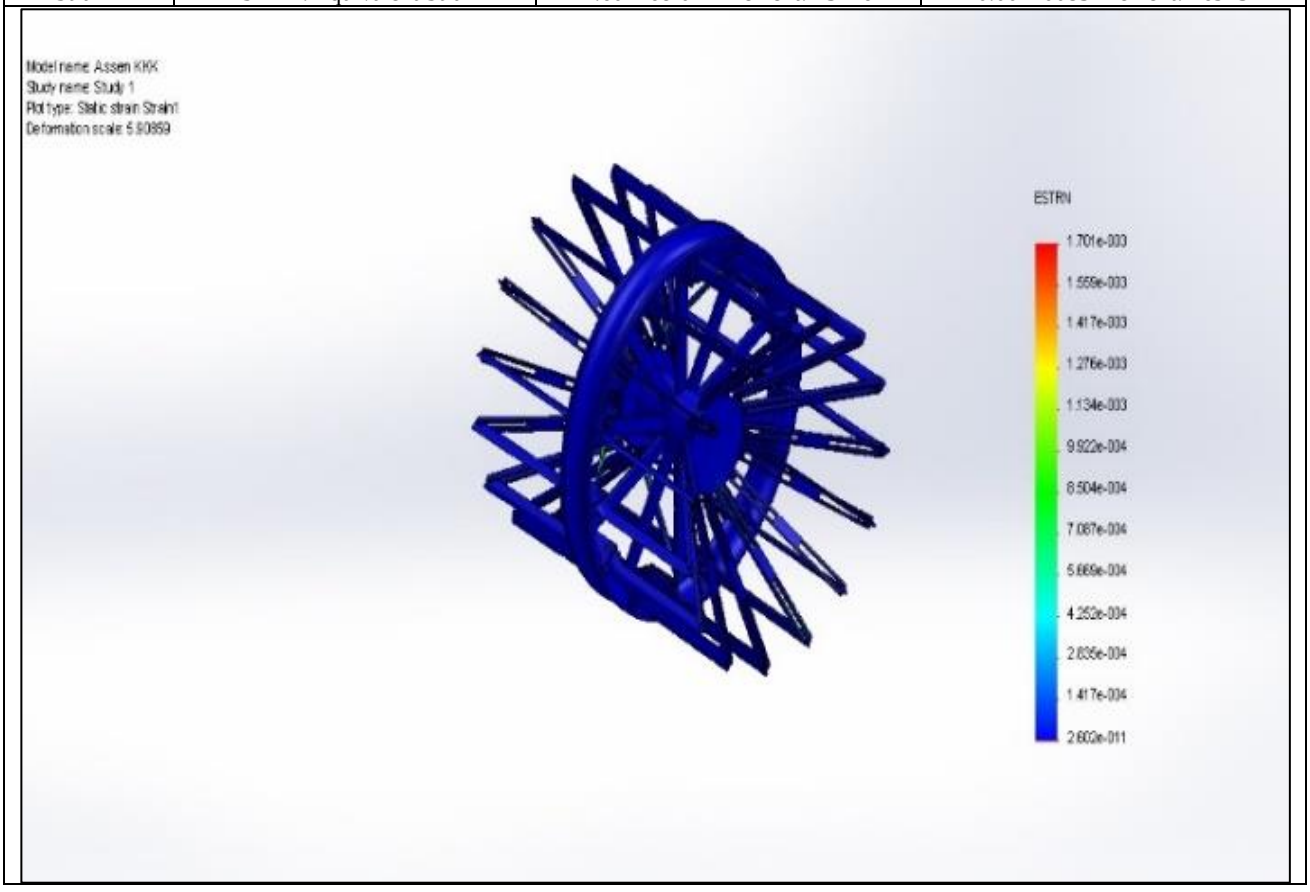
- **Displacement**

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 3139	20.877 mm Node: 42877



- **Strain**

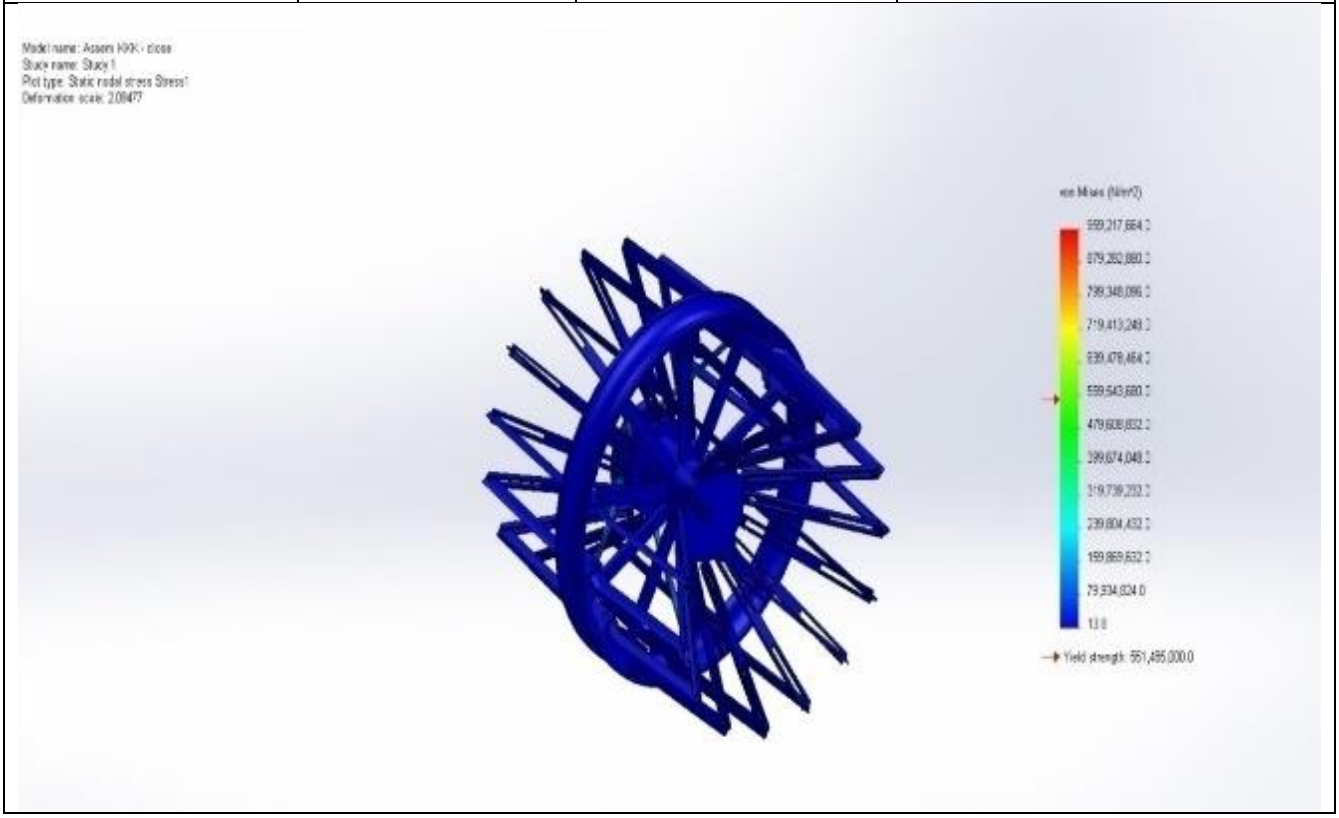
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.60176e-011 Element: 43476	0.00170085 Element: 16945



2. when the links are close

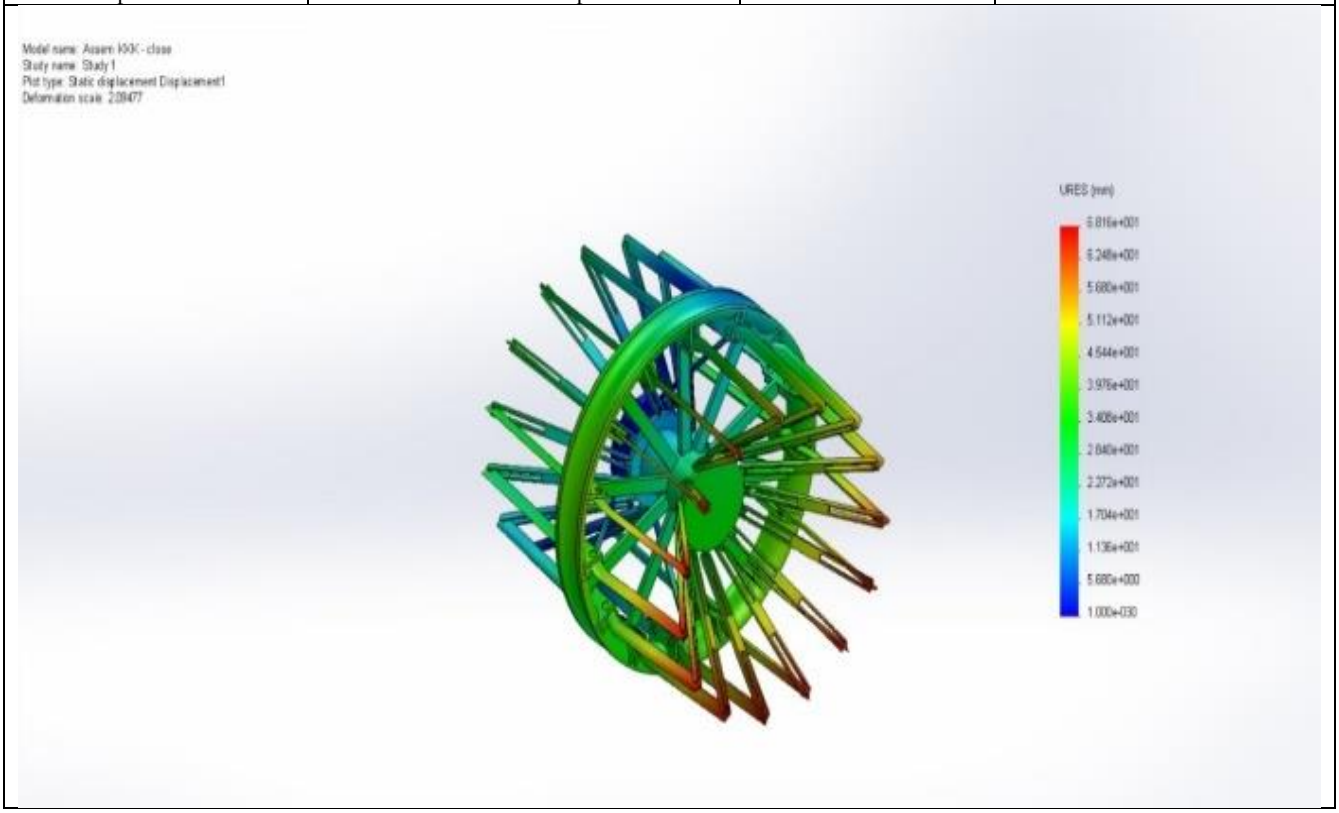
- **Stress**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	13.7757 N/m^2 Node: 52452	9.59218e+008 N/m^2 Node: 22762



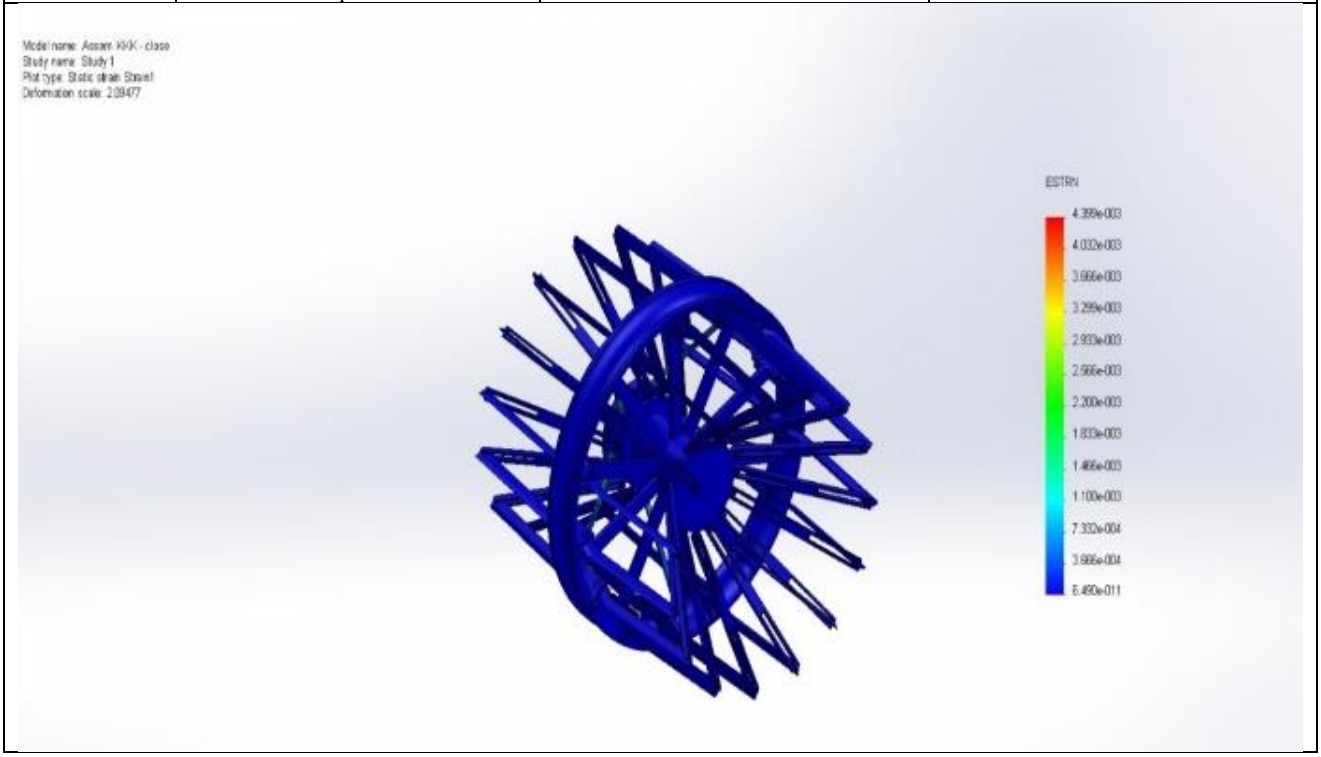
- **Displacement**

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 3139	68.1636 mm Node: 67982



- **Strain**

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.49029e-011 Element: 23851	0.00439901 Element: 16818

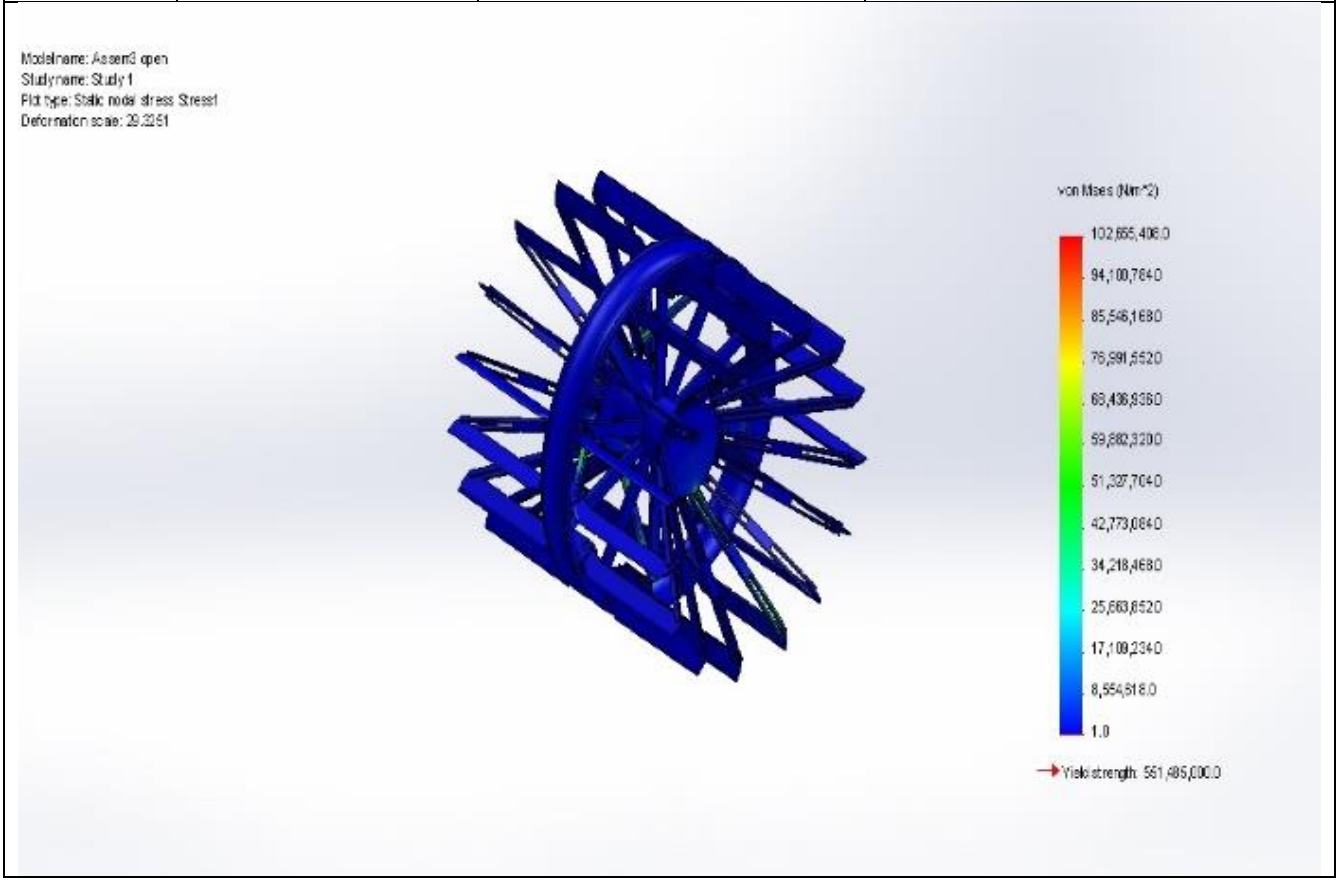


Study result for newly designed kinematic cage wheel

1. When the links are open

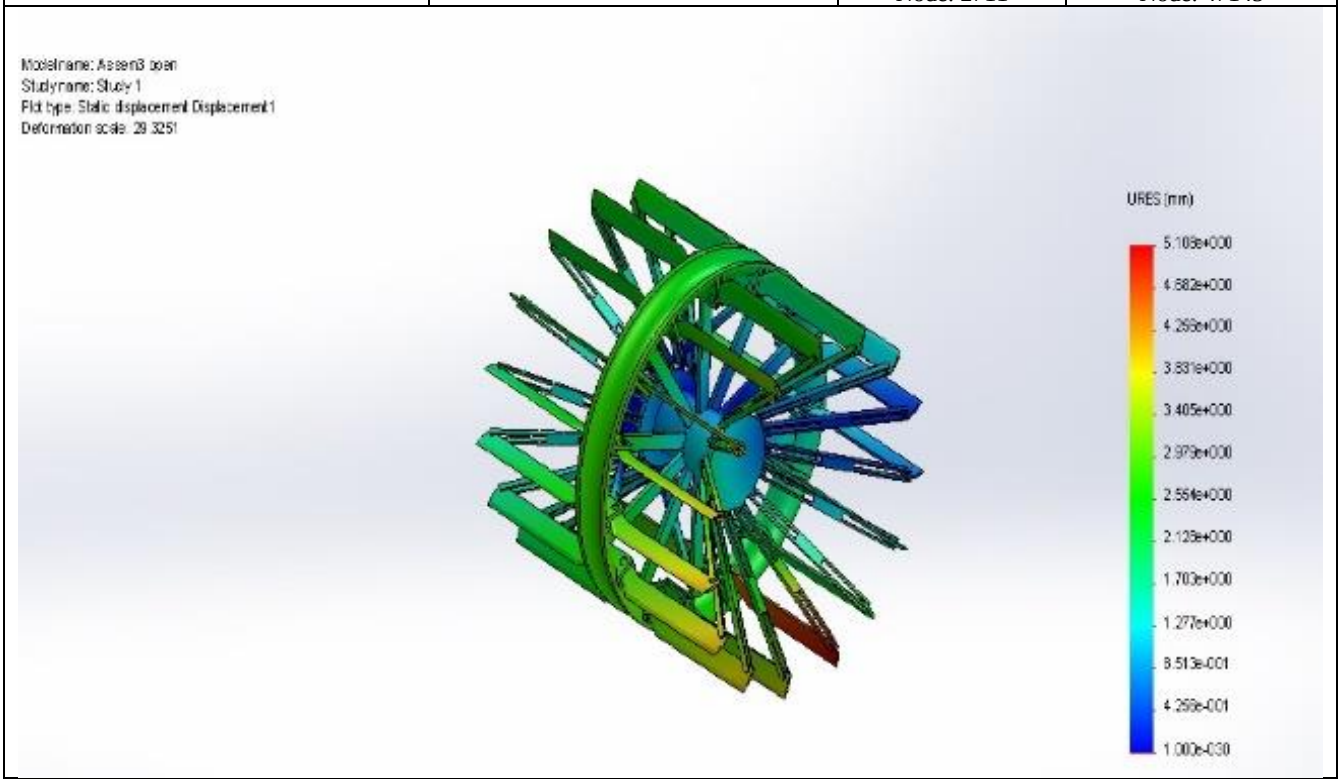
- **Stress**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.969444 N/m^2 Node: 72837	1.02655e+008 N/m^2 Node: 19593



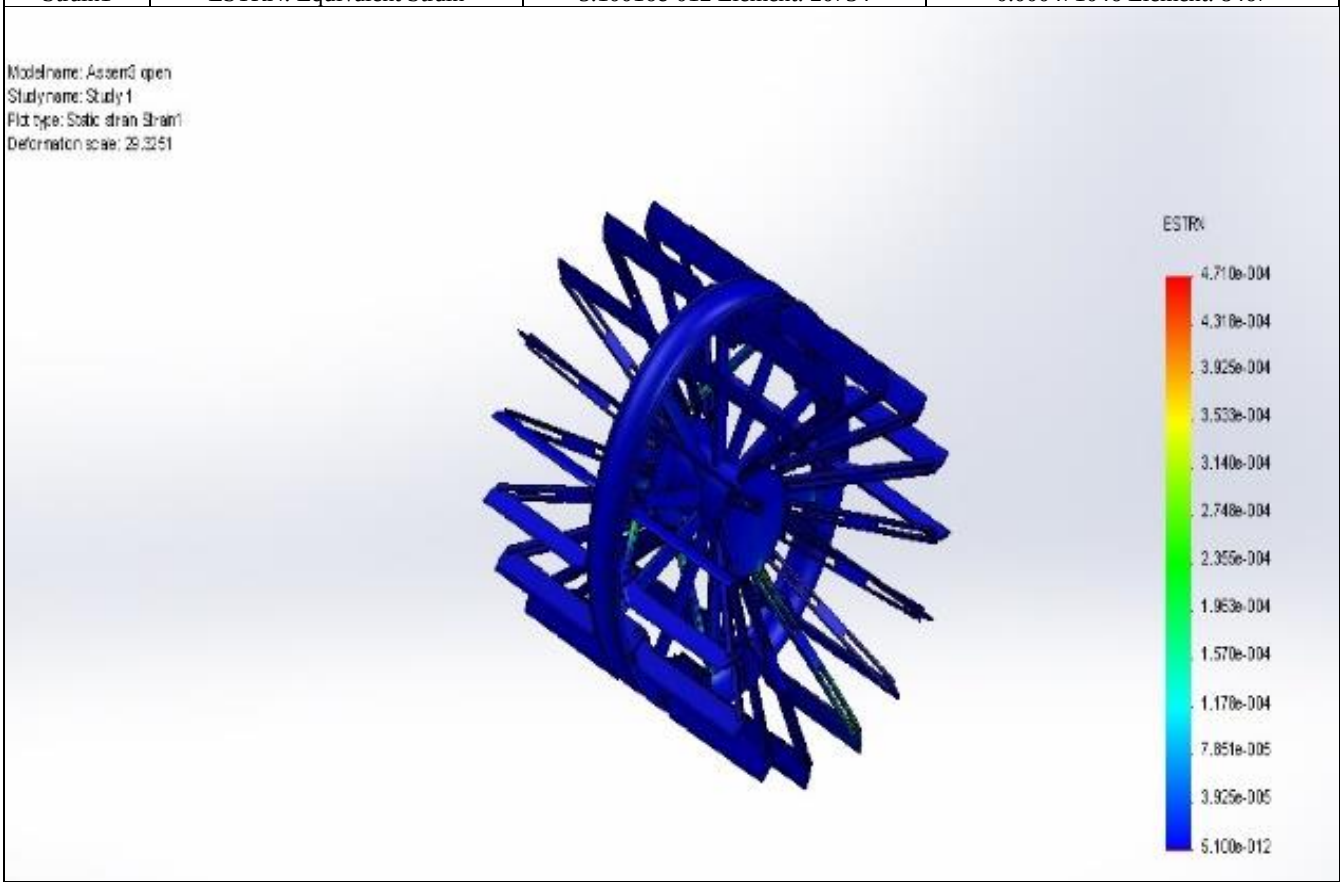
- **Displacement**

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 2711	5.10768 mm Node: 47145



- **Strain**

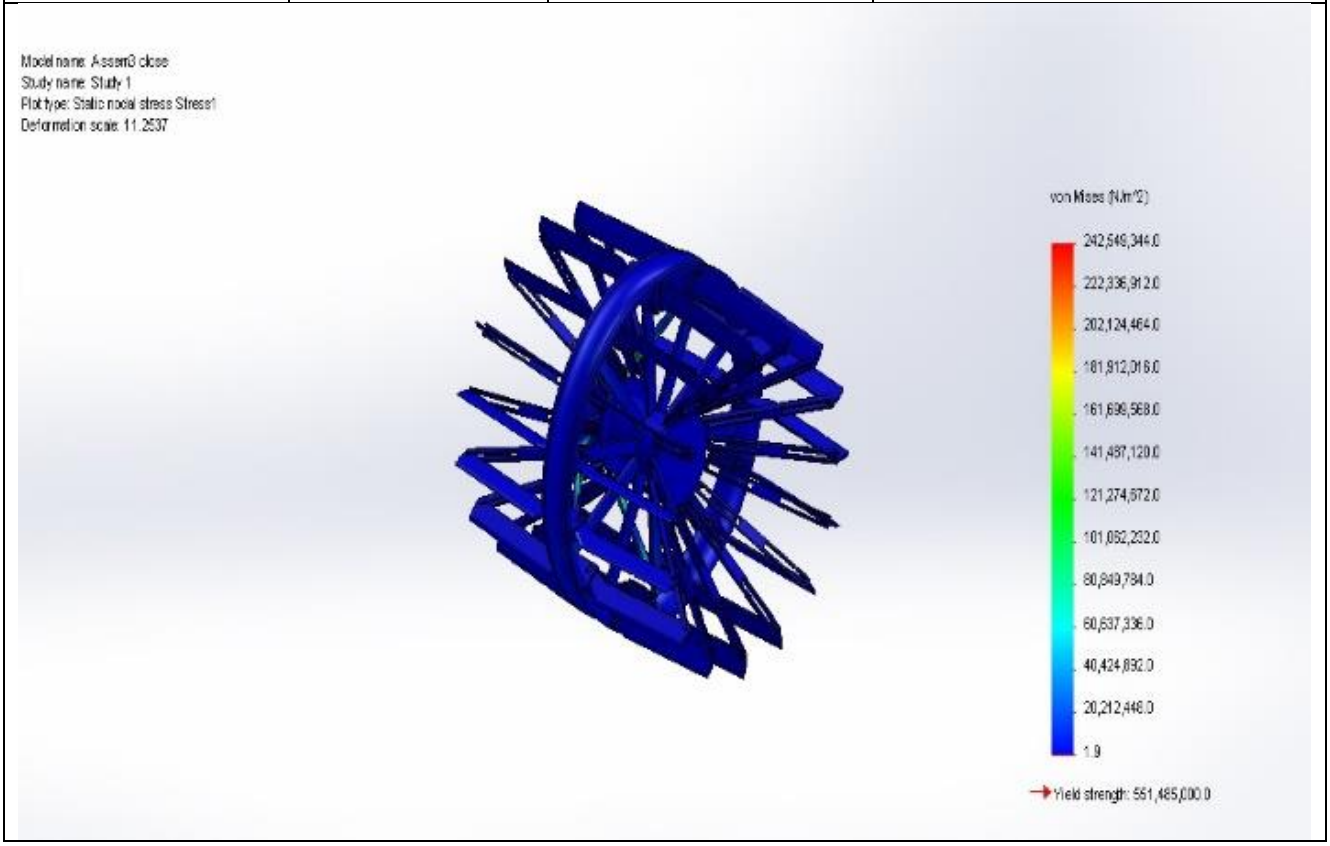
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.10016e-012 Element: 20734	0.000471046 Element: 8467



2. When the links are close

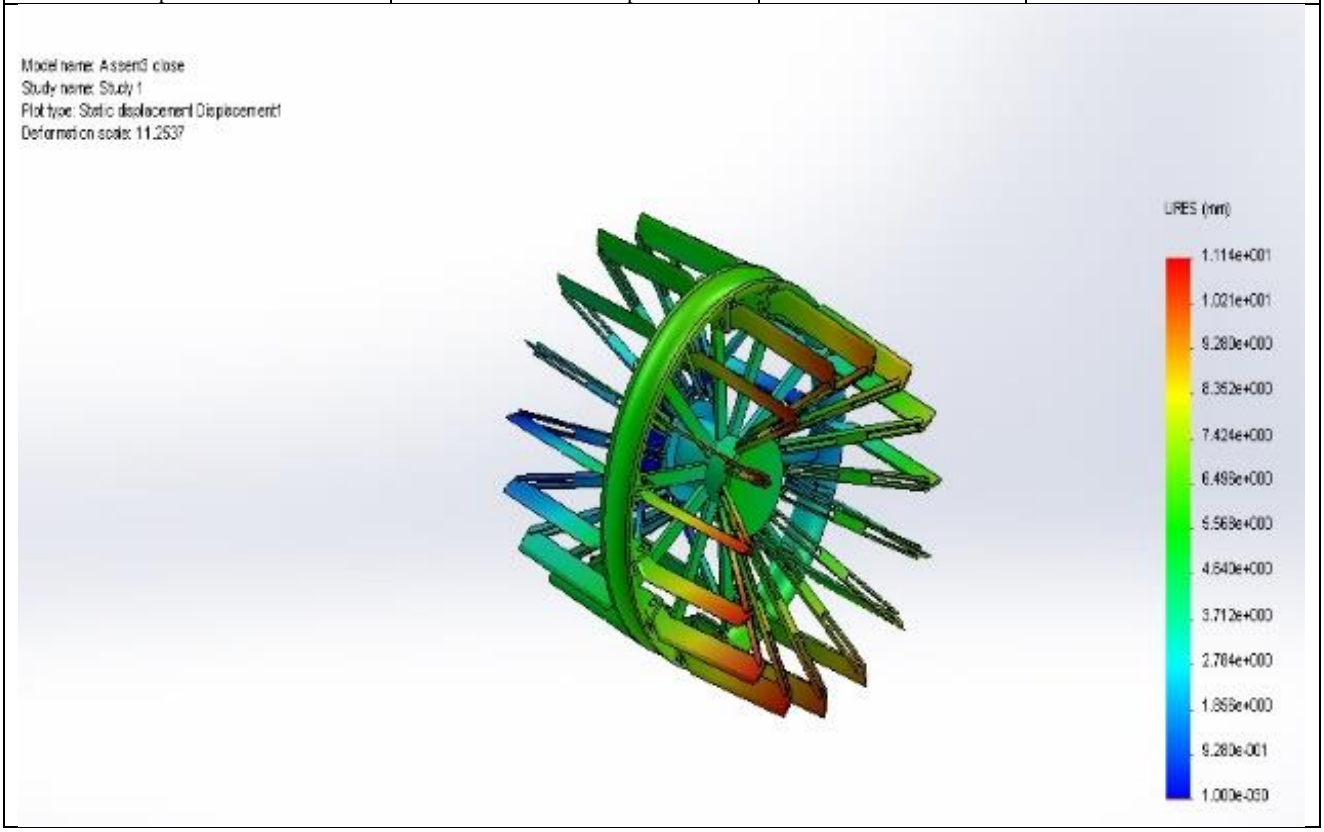
- **Stress**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.85806 N/m^2 Node: 83350	2.42549e+008 N/m^2 Node: 19580



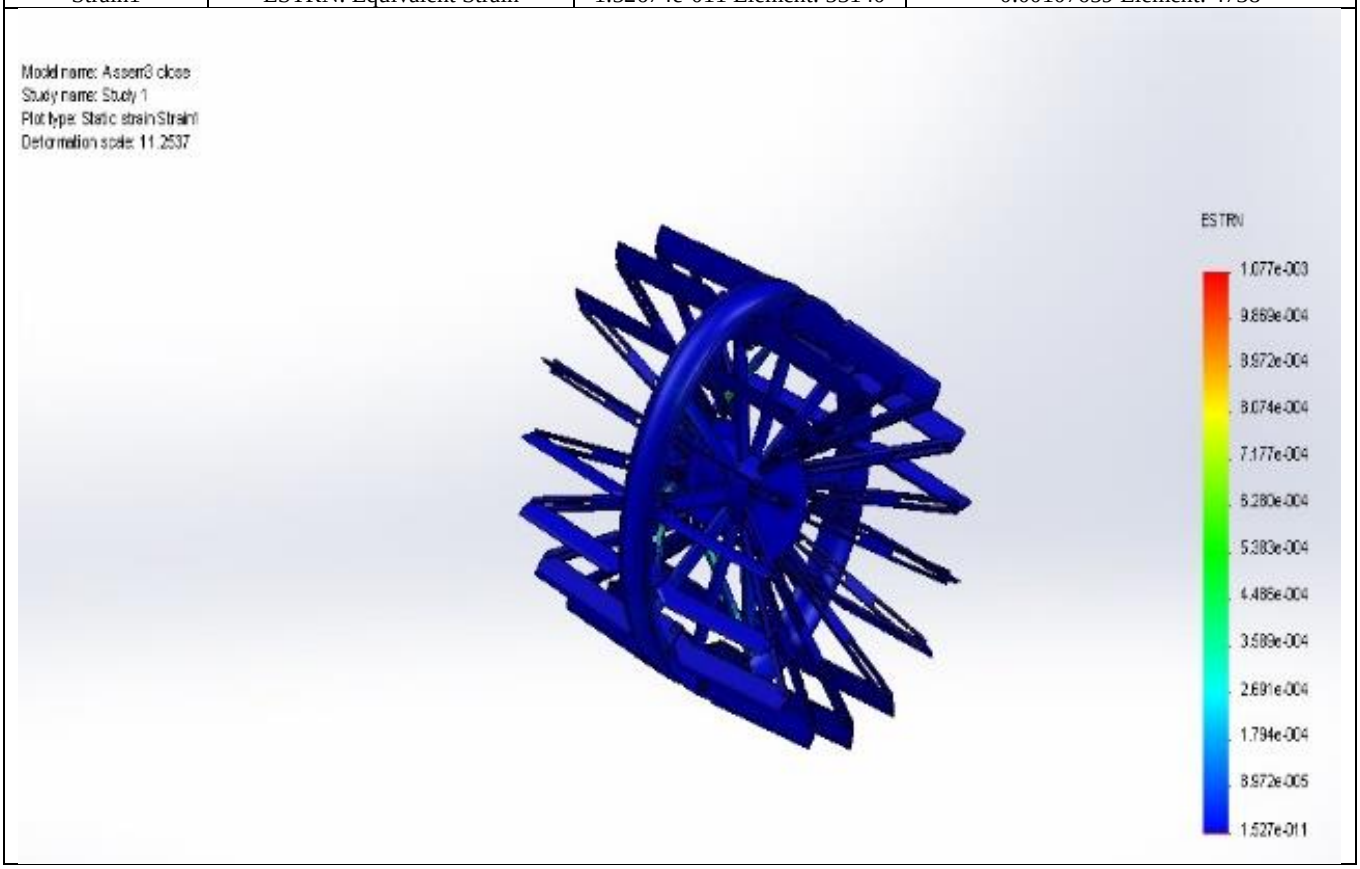
- **Displacement**

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 2726	11.1361 mm Node: 87792

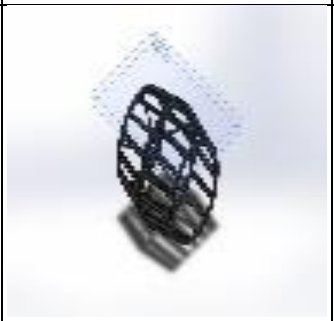
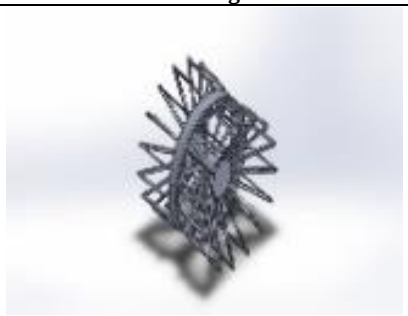


Strain

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.52674e-011 Element: 53140	0.00107659 Element: 4738



Result & Comparision

	Structure	Kinematic Cage Wheel		Modified Kinematic Cage Wheel	
	 Kinematic Cage Wheel	 Kinematic Cage Wheel		 Modified Kinematic Cage Wheel	
		OPEN	CLOSE	OPEN	CLOSE
Stress	3.26185e+007 N/M^2	1.29208e+008 N/M^2 Node: 64282	2.87196e+008 N/M^2 Node: 63563	1.02655e+008 N/M^2	2.42549e+008 N/M^2
Displacement	0.650714 Mm Node: 166	6.44602 Mm Node: 22688	15.3833 Mm Node: 29315	5.10768 Mm	11.1361 Mm
Strain	8.25001e-005 Element: 8405	0.000378882 Element: 34093	0.000767788 Element: 36223	0.000471046	0.00107659
Fos	8.45	2.13	0.96	5.37	2.27

Conclusion

The 3-D modeling of both standard cage wheels kinematic designed cage wheels and modified kinematic cage wheel is done and analyzed A comparative study has been made respect to Deflection, strain energy and stresses.

Our project is successful. The kinematic Cage Wheel is modified by us so as to fair unbeatable performance in wet land puddling operation for greater traction and pulverization of soil. The cage wheels have been designed to well prevent the roads from damage. Moreover, play down the strain of the tractor, and meet cultivation needs. The mode of operation is very simple. Finally it can be conclude that our designed hydraulically operated cage wheel is advantageous over the existing cage wheel. By changing the shape of the arm links, it can also be used for grass cutting, Land leveling.

Compare the results of modified kinematic cage wheel with kinematic cage wheel, the stresses are reduced and the main

thing is factor of safety improved nearly 3 times so our modified cage wheel is safe and better performance.

But the initial cost of this equipment is very high as there are two hydraulic cylinders used. However, 50% government subsidy is available for our half Cage Wheel as it causes no damage to roads. Farmers can get the same subsidy as our design also helpful without causing destruction.

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