MODIFY THE DESIGN OF KINEMATIC CAGE WHEEL TO IMPROVE THE FACTOR OF SAFETY (REDUCE THE STRESSES)

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ABSTRACT: *The present study deals with the modified design of kinematic cage wheel to improve the factor of safety. It derives from the convection way in the sense, that it tries to replace the structural conventional cage wheel with the kinematic cage wheel which have a double acting single cylinder mechanism. Here we have taken the conventional cage wheels and Mahindra 475 and previously we have designed kinematic cage wheel which have developed the stresses more than yield stress. To rectify this problem we are going to modify the design of kinematic cage wheel by changing the structural dimensions of the linkages, material of linkages and to introduce the new elements to decrease the stresses so that the resulting kinematic cage wheel will produce less stresses than the yield stress and also improve the Factor of Safety. The newly designed kinematic cage wheel mechanism is described, analyzed and evaluated in our project.The numerical analysis is carried via finite element analysis using SolidWorks software and compares the results of Stresses, deflection and strain of conventional cage wheel with the modified kinematic cage wheel. The aim of the project is to prove that modified kinematic cage wheel has sufficient strength to with stand fluctuating loads when compared to that of convectional cage wheel.*

1. INTRODUCTION

Agriculture is the backbone of Indian economy because 75 percent of India's population depends on agriculture or agro-industries. Apart from unique geographical conditions, India has been consistently making innovative efforts by using science and technology to increase production 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.

A tractor is a farm vehicle. Agricultural implements may be towed behind or mounted on the tractor and a tractor may also provide a source of power if the implement is mechanized. A farm tractor is used for pulling or pushing agricultural machinery or trailers, for ploughing, tilling, disking, harrowing, planting, and similar tasks. Tractors have revolutionized farming in much of the world. Among all these, cage wheel is very useful equipment for crops like paddy and wheat, for the purpose of wet land cultivation. Tractor Cage Wheel is used to mix the mud soil properly during the crop plantation. The Tractor Cage Wheels are made using heavy-duty angle and iron & steel material. It is suitable for fitting on all types of tractors due to its design. Like an iron wheel attached to the tractor rim, the Cage Wheels are also used for destroying big boulders into small pieces.

Commonly used in farming. Tractor Cage Wheel can be classified into two categories based on the mode of attachment.

They are *Fixed Tractor Cage Wheel (Half cage wheels) * Detachable Tractor Cage Wheel (Full conventional cage wheel)

2. Full Conventional Cage Wheel: In Detachable Tractor Cage Wheel, fitting can be done easily with nut and bolts. It gives relatively higher performance as compared to the half cage wheels. According to the requirements these cage wheels can be attached or detached very easily. So most of the farmers are preferring this type of cage wheel. As it is fully comprised of metallic structure it is also known as Full cage wheels.

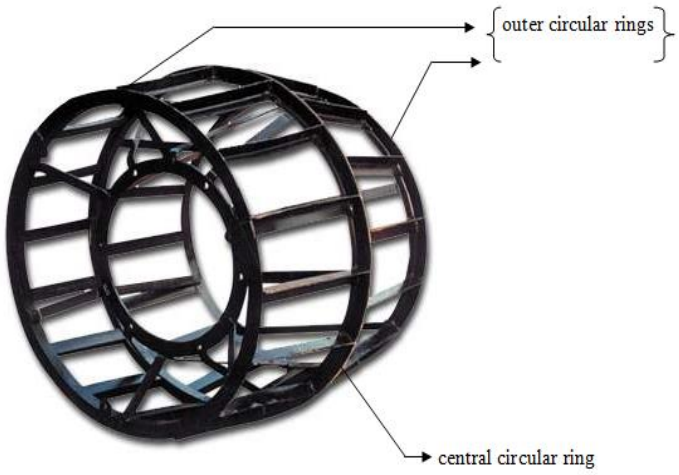


Fig.1.2.3 Tractor Full Cage Wheel

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 specific 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

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

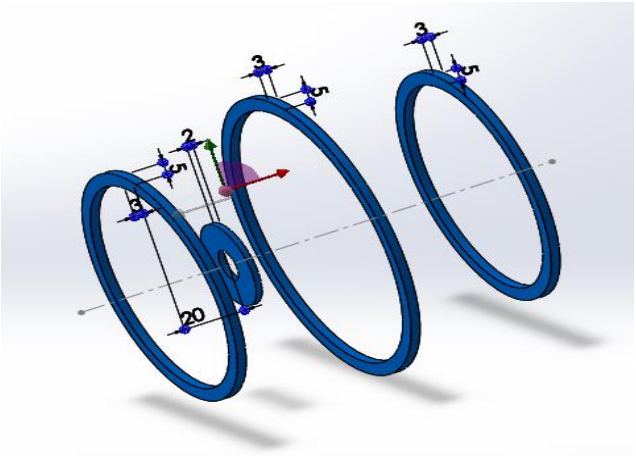
Length of each link=55 cm

Attachable disc:

Do'=40cm Di'=14cm

t=5cm

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



Dimensions of conventional full cage wheel

2. KINEMATIC CAGEWHEELMECHANISM

PARTS OF KINEMATIC CAGE WHEEL

The safety ring made of iron has come as a solution to the persistent problems often faced by drivers of tractors and other farm vehicles with caged wheels. This ring is wrapped around central large diameter ring on road conditions. But when it comes to on fields conditions, the iron ring has to be removed. With this arrangement roads are prevented from damage. But upsets down is still being a problem here. To come across that problem also, we have a plan to design a new mechanism. Here where we move on to the concept of our Designed CageWheel Mechanism. Their names itself tells the main difference, that Conventional cagewheel has no kinematic links while Designed cagewheel mechanism have. This mechanism involves two pistons and one cylinder.

The basic parts of designed cagewheel mechanism are,

1. Hydraulic cylinder with two pistons
2. Rim with attachable disc
3. Pull& push rod
4. Arm link

CONSTRUCTION

In our design the central large diameter ring is replaced by a rim, obviously tire is placed over the rim. Beneath the rim and along its circumference 15 rectangular plates are attached. These plates are having two holes with diameter around three centimeters. A hydraulic cylinder with two pistons, is arranged at the centre of the rim whose central axis exactly co-insides with the axis of rim. Spockets of rectangular cross sections are used to connect the rim and cylinder. To piston, 15 number of holes are made. 15 links are placed around the circumference, and are supported by rods. The Hydraulic cylinder with two pistons can be considered as the heart our mechanism.

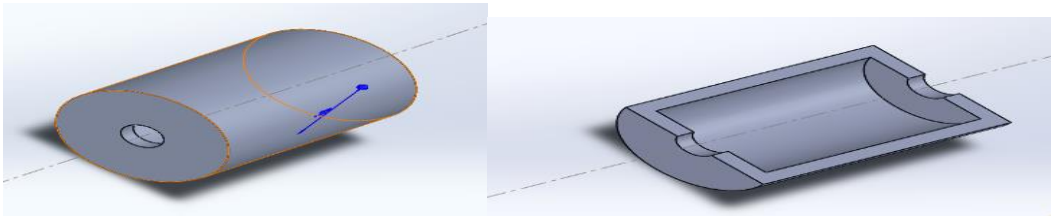
DESIGN OF PROTOTYPES:

Each of the mentioned parts are sketched (modelling) in SolidWorks software. But the dimensions are absolutely based on the conventional cage wheel. The material used has also taken same.

HYDRAULIC CYLINDER :

Hydraulic cylinder acts like a housing for two pistons. Hydraulic fluid enters into the cylinder and pushes the two pistons linearly outside along the axis of the cylinder. Two pistons slide nearer to each other whenever the hydraulic fluid is retracted. Rectangular spocketss are projected on to its surface. So it is useful to support the rim.

Key command used: Revolved boss/Base

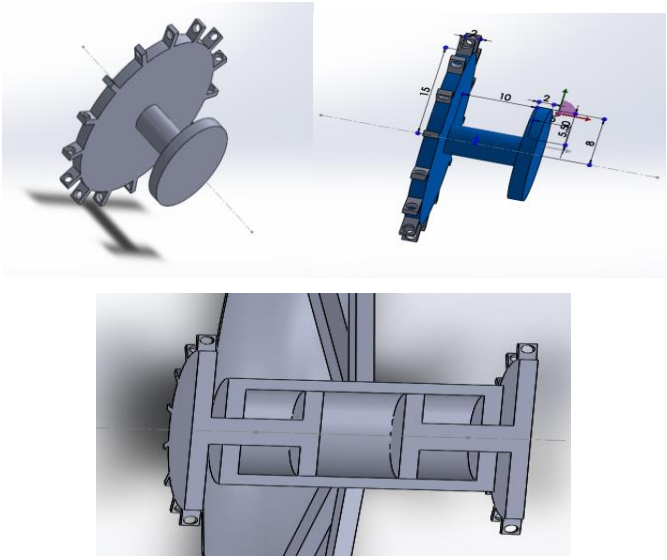


Isometric and Sectional views of Hydraulic cylinder

PISTONS:

In this arrangement, we require two pistons of similar dimensions. Piston has a diameter equal to the inner diameter of Hydraulic cylinder. To the end of the piston rod a large diameter disc is attached which further has rectangular strips around its circumference at equal spaces. These Rectangular strips are provided to accommodate one end of Pull& push rods.

Key command used: Revolved boss/Base, Circular pattern.



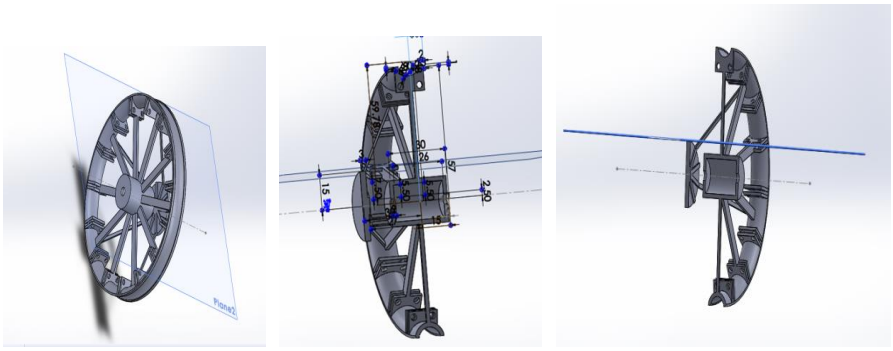
Pistons with large circular disc and their dimensions

RIM WITH ATTACHABLE DISC:

Weight of the farm tractor is transferred to the ground by means of Rim. Hydraulic cylinder and Rim are connected together with Spockets having rectangular cross section.

Rim is also in contact with Attachable disc. The attachable disc is useful to connect to the rear axle of farm tractor.

Key commands used: Revolved boss/Base, Circular pattern, Extruded boss/Base, Extruded cut

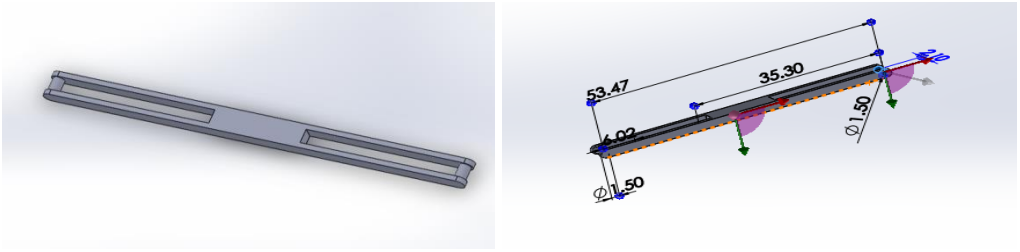


Different views of Rim with Attachable disc

PULL& PUSH ROD:

Pull& push rod converts linear motion of pistons into rotary motion of Arm links. It can also be called as Connecting rod, because it connects Arm link and the End of piston.

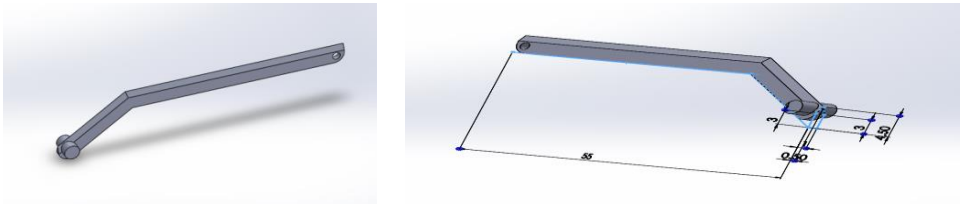
Key commands used: Extruded boss/Base, Mirror.



Isometric view and dimensions of pull& push rod

ARM LINK:

Main Working element in this mechanism is Arm link. Extruded end of Arm link is connected to Rim, other end is connected to Pull& push rod. Arm link has rotary motion.
Key commands used: Extruded boss/Base, Swept boss/Base,

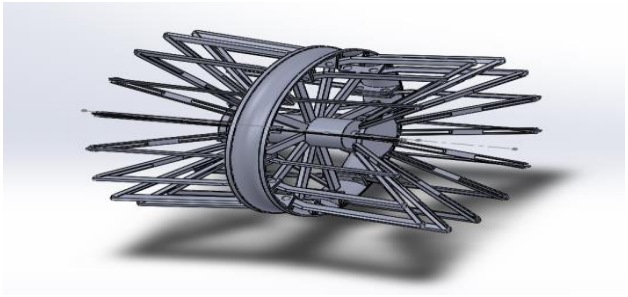


Isometric view and dimensions of arm link

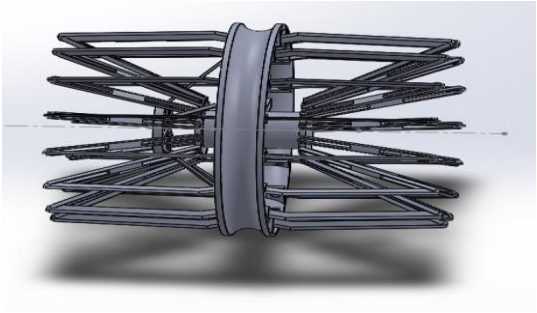
ASSEMBLY OF ESSENTIAL PARTS:

After all the parts are designed, Each of the parts as to be grouped properly to get final useful assembly. For this task also SolidWorks software is used.

Key commands used: Mate, Mirror, Circular Pattern .After the assembly, the final design is as given below.



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 comparitively 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 retrieved. According to the requirements the links are made to open wide and bring back to the close position.

Drawback of the kinematic cage wheel:

Analysis is done on the kinematic cage wheel. 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.

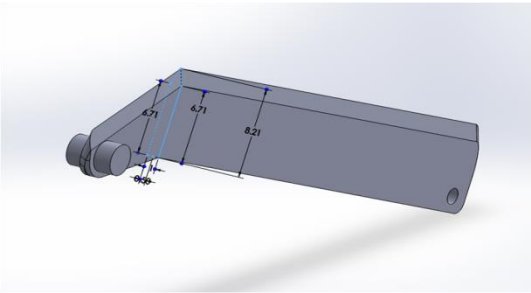
The following part dimensions are modified

1.Arm link

2.Rim with attachable disk

Arm link

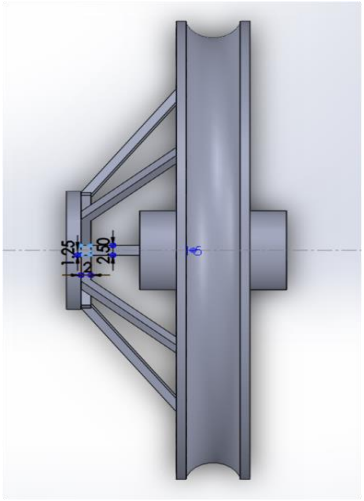
The width of the arm link is increased so that it is placed properly on the road surface. Same level is maintained in the central ring and the arm link, so that there is uniform distribution of the load.



Arm Link

Rim with attachable disk

Analysis is done on the single part i.e, Rim with attachable disk and found that it is deformed at the attachable links. So the links joining the attachable disk and the central ring dimensions are changed. So that it is strong enough to withstand the loads.



Rim with attachable disk

ANALYSIS OF CAGE WHEEL USING SOLIDWORKS

All the analysis for the cage wheel is done by using SolidWorks 2013. The same parameters are used as that of conventional cage wheel. SolidWorks acted as a platform to perform both modeling and analysis. The constraint is given at the attachable disc. It seems just like a Cantilever Beam. The stress and deflection analysis is done for conventional, kinematic cage wheel and modified kinematic cage wheel using SolidWorks software. The results for the three is compared.

CALCULATIONS

For a tractor to stay upright, 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.

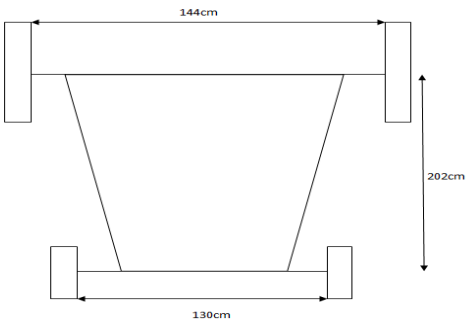


Fig.5.1 CENTER OF GRAVITY

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

Centroid=(x,y)

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

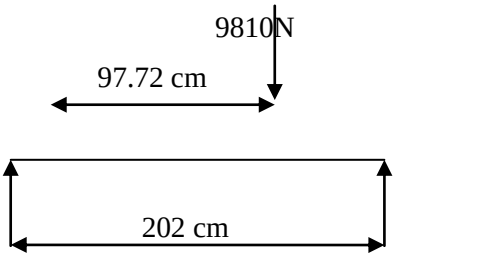
$$= \frac{[(130*202)*101]+[(14*202)*(202/3)]}{(130*202)+ (202*14)}$$

= 97.72 cm

So the center 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 simply supported beam.



Taking Moment acting about

(R_f) ,R_r*202)-(9810*97.72)=0

(Sum of moments about R_f, it is=0)

R_r=4745.71N

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.

5.1.1 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 performance. 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=$\mu*R_n$

=0.35*4745.71 {μ=0.35,R_n=4745.71 N}

=1660.99 N

Reaction torque T=Frictional force* radius of central ring

=1660.99*0.56

=930.15 N-m

Reaction torque T=930.15 N-m

T=930.15 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=1660.99*0.58

=963.37N-m

Now gathering all the data,

Torque values:

1. on conventional cage wheel=930.15 N-m
2. on designed cage wheel

- While the links are in fully closed position=963.37 N-m
- While the links are in fully open position=963.37 N-m

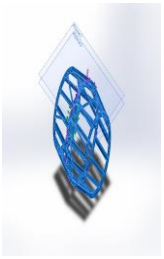
Reaction torque T=963.37 N-m

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

ANALYSIS

Analysis part includes Studying material properties, Study properties. applying pressure, Meshing. Values 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

Model Reference	Properties	
	Name:	**Ductile Iron**
	Model type:	**Linear Elastic Isotropic**
	Default failure criterion:	**Max von Mises Stress**
	Yield strength:	**5.51485e+008 N/m^2**
	Tensile strength:	**8.61695e+008 N/m^2**
	Elastic modulus:	**1.2e+011 N/m^2**
	Poisson's ratio:	**0.31**
	Mass density:	**7100 kg/m^3**
	Shear modulus:	**7.7e+010 N/m^2**
	Thermal expansion coefficient:	**1.1e-005 /Kelvin**

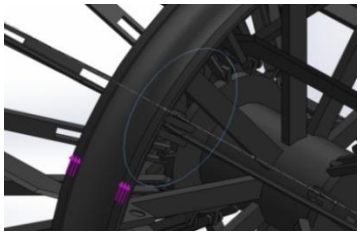
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

ON NEWLY DESIGNED KINEMATIC CAGE WHEEL

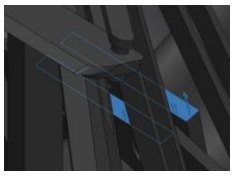
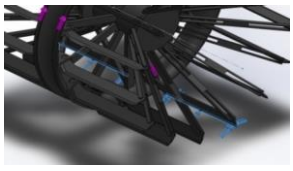
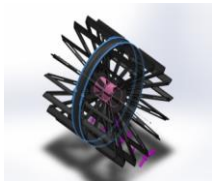
1. When the links are opened

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**0.217091**	**-1004.62**	**-214.47**	**1027.26**
Reaction Moment (N·m)	**0**	**0**	**0**	**0**

Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Type:** Apply normal force **Value:** -618.96 N
Force-2		**Entities:** 4 face(s) **Type:** Apply normal force **Value:** 1288.73 N
Torque-1		**Entities:** 2 face(s) **Reference:** Face< 1 > **Type:** Apply torque **Value:** 963.37 N·m

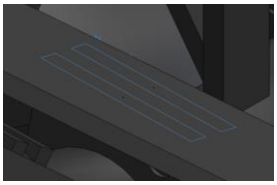
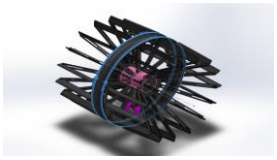
2. When the links are closed

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**-4.24543**	**-4641.87**	**985.927**	**4745.42**
Reaction Moment(N·m)	**0**	**0**	**0**	**0**

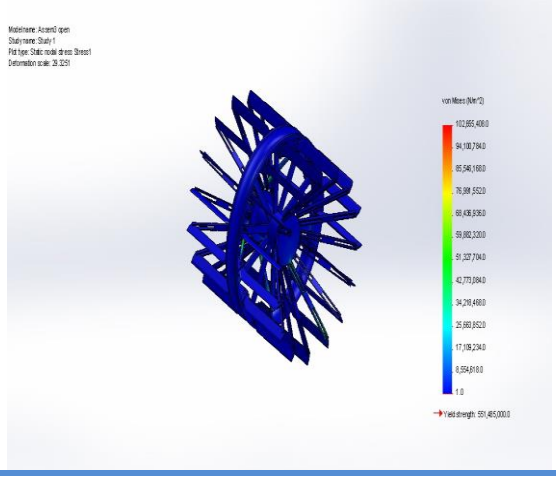
Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Type:** Apply normal force **Value:** -4745.71 N
Torque-1		**Entities:** 2 face(s) **Reference:** Face< 1 > **Type:** Apply torque **Value:** 963.37 N·m

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



Force applied on Modified kinematic Cage Wheel =4745.71N

Torque applied on modified Cage Wheel =963.37 N-m

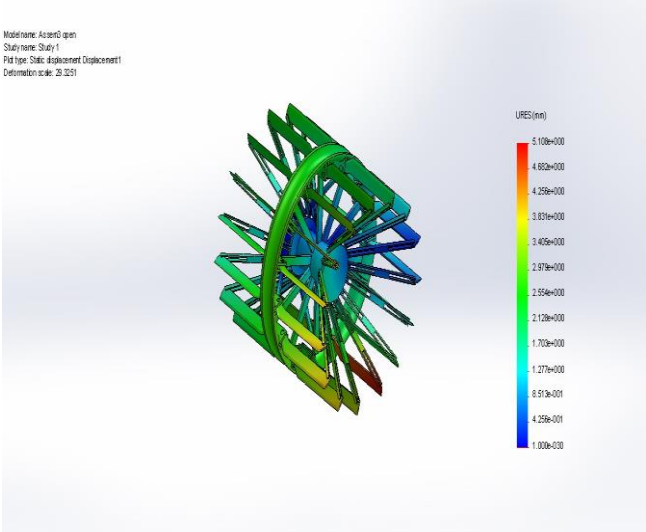
Minimum stress=1 N/m^2

Maximum stress=102665408N/m^2

Blue colour indicates the area of Minimum stress, while the red zone indicates Maximum stress. It means failure may occur at that red zone.

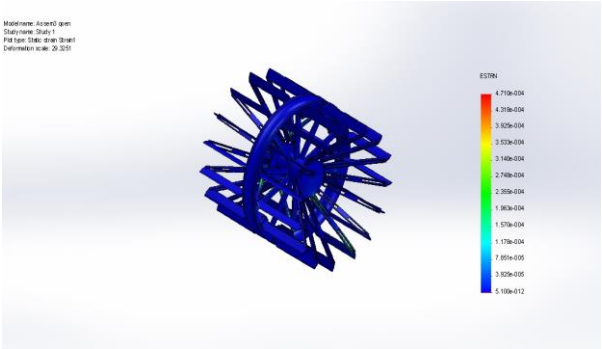
➢ **DISPLACEMENT**

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



➢ **STRAIN**

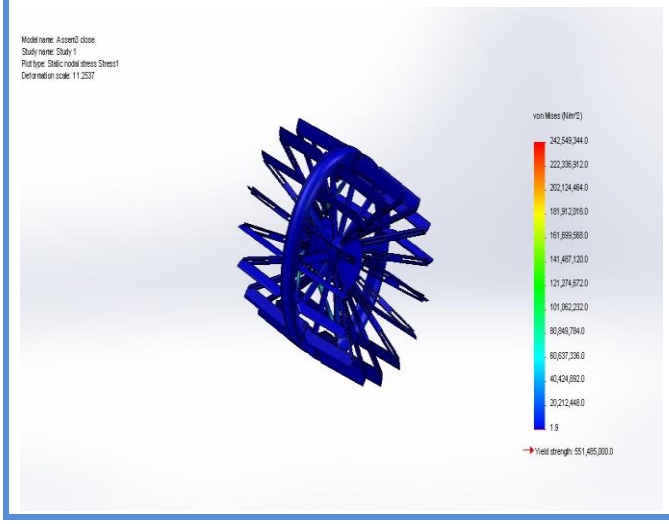
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.10016e-012 Element: 20734	0.000471046 Element: 8467



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



Force applied on Modified kinematic Cage Wheel =4745.71N
Torque applied on modified Cage Wheel =963.37 N-m

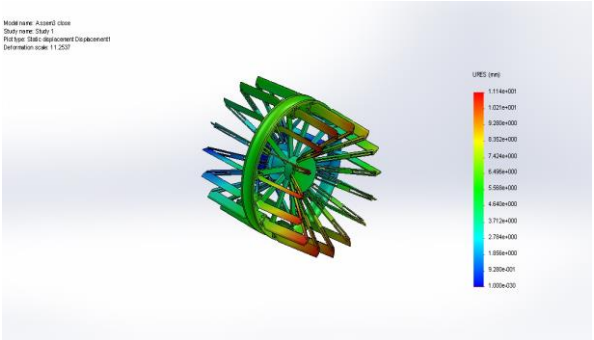
Minimum stress=1 N/m^2

Maximum stress=242549344N/m^2

Blue colour indicates the area of Minimum stress, while the red zone indicates Maximum stress. It means failure may occur at that red zone.

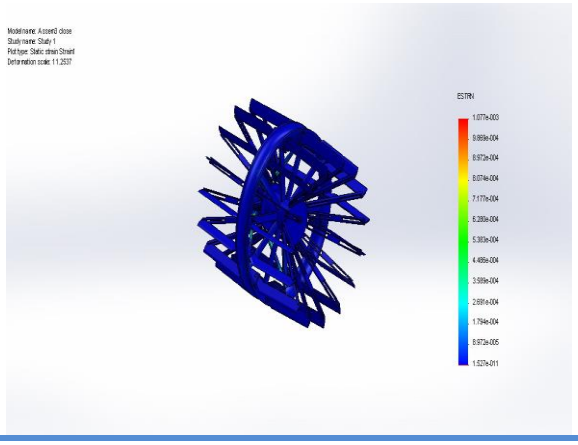
➢ **DISPLACEMENT**

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

Type	**Stress**	**Factor of Safety**
Newly designed kinematic cage wheel(open)	102665408 N/m^2	5.37
Newly designed kinematic cage wheel(close)	242549344 N/m^2	2.27

CONCLUSION

The dimensions of the arm link and the rim with attachable disk of the kinematic cage wheel are modified and 3-D modelling of the parts is done in the SolidWorks software. A comparative study has been made with respect to Deflection, Strain energy, stresses and yield strength.The newly designed kinematic cage wheels have reduced the stresses compared to the previously designed kinematic cage wheel. The factor of safety for the kinematic cage wheel is also increased which indicates that the design is safe. The cage wheels which have been designed are more suitable for Indian roads because it reduced the damage of roads by changing the angular position of links. The advantage of this cage wheel is it can used for grass cutting and land levelling by changing the shape of the arm links.