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DESIGN AND STRUCTURAL ANALYSIS OF AUTOMATIC REVERSE LOCKING RACK MECHANISM FOR CAR JACK

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Abstract:

A screw jack is a type of jack which functions by the turning of a lead screw. It is commonly used to lift heavy load to a certain height. A good example is the car-jacks. In the case of a screw jack, due to the wear of trunnion's thread it may cause the slippage of the lead screw and leads to the sudden fall of the vehicle which is been lifted by the screw jack. The statement of the problem has led to the motivation of designing the automatic reverse locking rack mechanism for car jack.The automatic reverse locking rack mechanism is a proposed system and method for preventing a vehicle from sudden fall when jack fails to support the vehicle for certain period of time. The work presented here reveals the construction and design of the screw jack safety system. The design is made to be compact for the ease of use. The best suitable material for the components were taken into account which are to be analyzed by finite element analysis method. Along with the results that obtained can give the conclusion about the stress, strain and maximum load carrying capacity with minimum deformation.

Keywords **—Screw jack, Automatic reverse locking rack mechanism, safety system.**

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I. INTRODUCTION

The jack is a device which is usually used to raise the significant masses. It is one of the most widely used accessories for lifting the vehicles. Whatever the problem would be like puncher of the tyre, jack is performed to lift the vehicle to certain height for a specific period of time. During this period in case of scissor jack, the power screw with certain friction coefficient helps for self-locking mechanism, however if the trunnion's internal thread is worn out. It may lead to sudden fall of the vehicle. To arrest the accidental fall. This automatic reverse locking rack mechanism plays its role to prevent the sudden fall of the vehicle. The rack type-ratchet pawl mechanism serves the purpose to allow the rack to move linearly in one direction only. It preventing the ratchet rack from falling in reverse direction.

Scissor jack is one of the powerful lifting jacks operated by a screw in a horizontal position. It gets lengthens and shortens the horizontal diagonal of the parallelogram which consisting of linkages of the jack. It consists of metal components that connects together in a scissor-like shape between the top and base of the jack. Those metal components act as an adjustable lift using the scissor mechanism by changing its height and to withstand a wide range of weight.

The rack type-ratchet pawl mechanism plays an important role in providing one way transmission and safety against uneven and heavy loading conditions. The ratchet is a rack that has teeth cut out of it and a pawl that follows as the rack moves longitudinally. In recent analysis of the fatal accident statistics which showed the reversing activities were involved in 12 percentage of all the fatal transport accidents. Accidents during reverse movement results less in injury but more damage to vehicles and other human properties.

In this study, the safety system automatic reverse locking rack mechanism were designed and static structural strength were assessed.

II. PROBLEM DEFINITION

The purpose of the study was defined below,

- Car jack has no safety system to arrest the fall.
- However, power screw with certain friction coefficient helps for self-locking mechanism.
- If the trunnion's internal thread is worn out. It may lead into sudden fall.
- To arrest that accidental fall and to give an additional support for the jack.
- This automatic reverse locking rack mechanism serves its purpose.

III. METHODOLOGY

The objectives of the project are as follows,

- To develop structural modelling of the safety system with automatic reverse locking rack mechanism.
- To perform finite element analysis of the designed model.
- Suitable material study.
- To Study the load factors.
- To investigate the stress, deformation induced in the model.

A. *Materials*

The aim of this project is to design and analyse the safety system by various parameters involved in it. This material of model will give more strength and will give long life. Rack type ratchet pawl mechanism is used here to provide one way motion only to arrest the sudden fall. The following are the materials that to be used in the components.

- EN9 (Normalize) for rack type ratchet component.
- C20 (Steel Forging) for pawl component.
- ASTM A36 STEEL (Mild Steel) for all the remaining components. The Table 1 shows the materials and their physical properties to be used in the components for analysis.

TABLE I
MATERIAL AND THEIR PROPERTIES OF EXISTING AND SELECTED MATERIAL

Properties	Materials		
	ASTM A36 STEEL	**C20**	**EN9**
Density [Kg/m3]	7850	7850	7800
Yield tensile strength [Mpa]	250	360	355
Ultimate tensile strength [Mpa]	550	425	700
Youngs modulus [Mpa]	$200x10^3$	$210x10^3$	$206x10^3$
Bulk modulus [Mpa]	$140x10^3$	$175x10^3$	$171x10^3$
Shear modulus [Mpa]	$79x10^3$	$80x10^3$	$79x10^3$
Poisson ratio	0.26	0.3	0.3

B. *Design calculations*

The weight of the car is almost 1.5 ton, where the weight of the axle is about 60% of 1.5 ton. So, the weight of the front axle is considered to be 450 Kg. The axle lies on the rotatory support of the model which has the 80 mm diameter

Weight = 450 kg

Load = 450 x 9.81 = 4414.5 N

Diameter = 80 x 10^{-3} m

Area = (3.141/4) x $(80 \times 10^{-3})^2$ = 0.005026 m^2

Pressure = 4414.5 / 0.005026 = 878332.67 N/m^2

The pressure of 878332.67 pascal or N/m^2 that acts on the rotatory support. Then the model is to be analysed whether it can withstand that load which acts on it.

IV. MODEL OF THE SAFETY SYSTEM

There are several components which are used for designing the safety system were modelled using SolidWorks whose dimensions and their respective views were shown below,

1) ***Base plate:***It hold the system. The Fig. 1 shows the model of base plate with its dimensions.

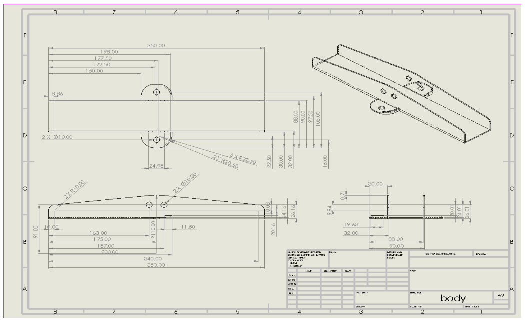

Fig. 1 Model of base plate

2) ***Foldable support arm:*** It connects the base plate and the automatic reverse locking rack mechanism. The Fig. 2 shows the model of the foldable support arm with its dimensions.

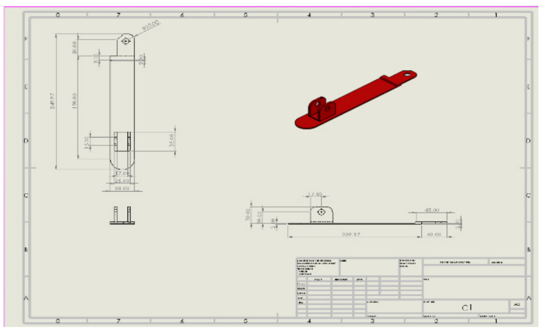

Fig. 2 Model of foldable support arm

3) ***Rack type ratchet:*** It allows the linear motion in only one direction while preventing the motion in reverse direction. The Fig. 3 shows the model of the rack type ratchet with its dimensions.

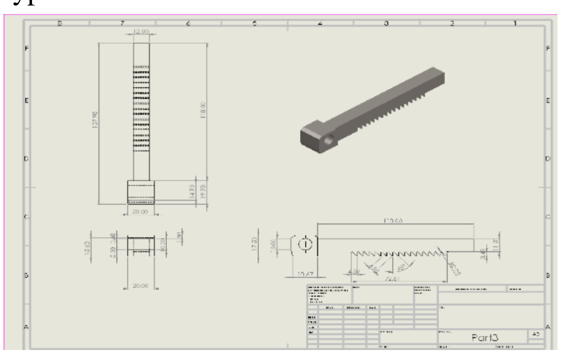

Fig. 3 Model of rack type ratchet

4) ***Pawl:***The pawl is a mechanical device that allows the linear motion in only one direction. The Fig. 4 shows the model of the pawl with its dimensions. However, it will catch the rack type ratchet by locking it against the tooth and preventing any further motion in that direction.

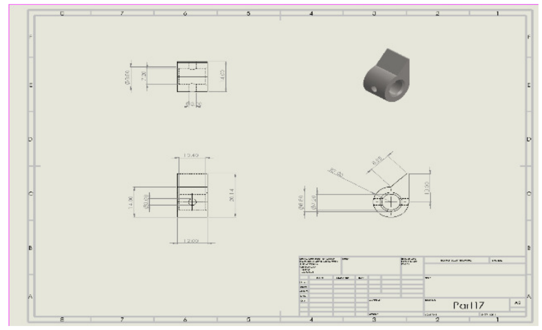

Fig. 4 Model of pawl

5) ***Connecting rod:***It that connects the pawl with the handle which is to be operated. The Fig. 5 shows the model of the connecting rod with its dimensions. It rotates about its axis.

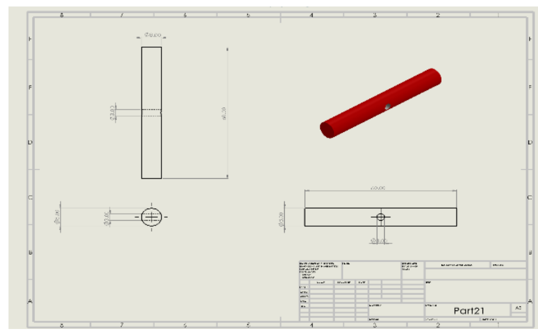

Fig. 5 Model of connecting rod

6) ***Handle:***The handle is the device that connects the connecting rod. It works by gravity when the rack type ratchet moves out it pop over the case. When the rack falls in the reverse direction the pawl arrests it with the help of handle which makes contact with the casing. The Fig. 6 shows the model of the handle with its dimensions.

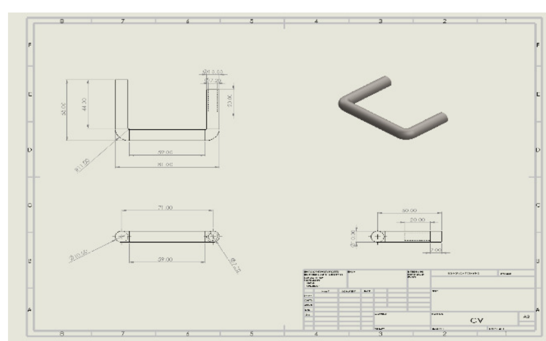

Fig. 6 Model of handle

7) ***Casing:***It is a case which consist of the rack type ratchet, pawl and handle. This whole setup is known as automatic reverse locking rack mechanism. The Fig. 7 shows the model of the casing with its dimensions.

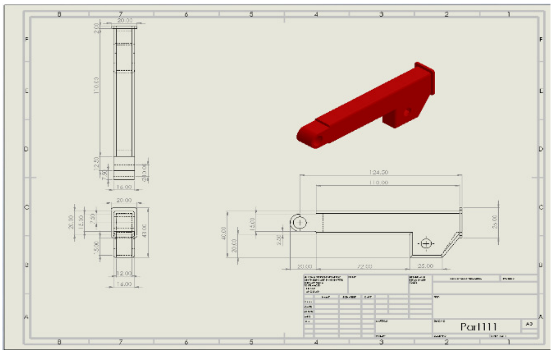

Fig. 7 Model of casing

8) ***Clamp:***It is used to connect top plate with rack by fastening it. The Fig. 8 shows the model of the clamp with its dimensions.

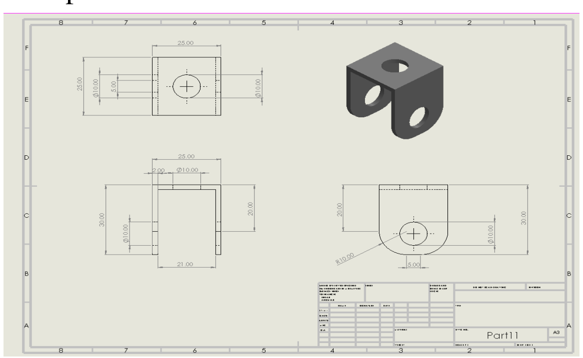

Fig. 8 Model of clamp

9) ***Top plate:***The top plate connects both the rack type ratchet. It is the place where the total load distributes to the rack in both sides. It has a circular hole were the rotatory support to be placed. Fig. 9 shows the model of the top plate with its dimensions.

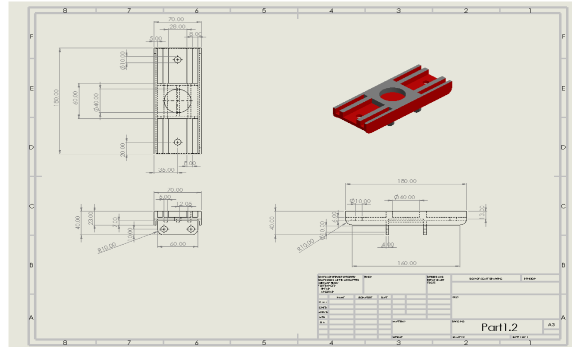

Fig. 9 Model of top plate

10) ***Rotatory support:***It helps to grip the vehicle. It can able to rotate itself by 360 degrees. It is the place where the load acts over it. The Fig. 10 shows the model of the rotatory support with its dimensions.

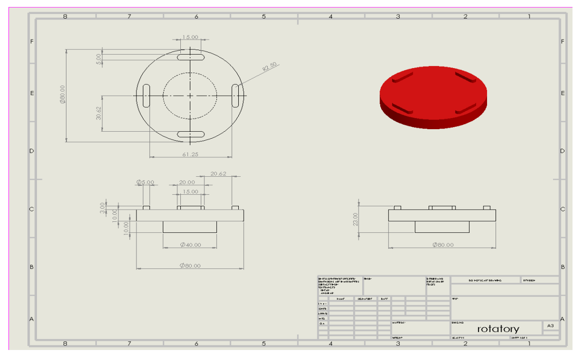

Fig. 10 Model of rotatory support

V. ASSEMBLY OF THE SAFETY SYSTEM

This assembly is created by mating with several part models which is modelled using solid works software. The part models which are used here are follows,

- Rack type ratchet
- Pawl
- Connecting rod
- Handle
- Casing

The Fig. 11 shows the assembled view of automatic reverse locking rack mechanism.

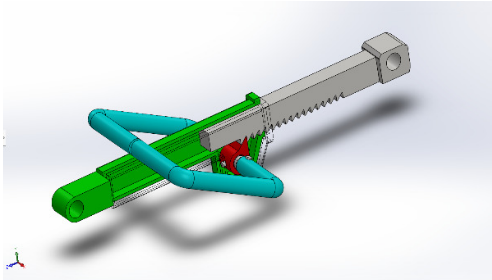

Fig. 11 Assembled view of automatic reverse locking rack mechanism

The Fig. 12 shows the assembled view of the safety system using automatic reverse locking rack mechanism for car jack. The foldable arms are used to fold the setup to make the system to be compact. The Fig. 13 shows the assembled view of folded safety system.

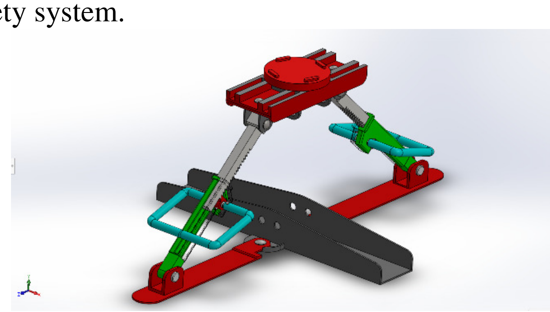

Fig. 12 Assembled view of safety system using automatic reverse locking rack mechanism for car jack

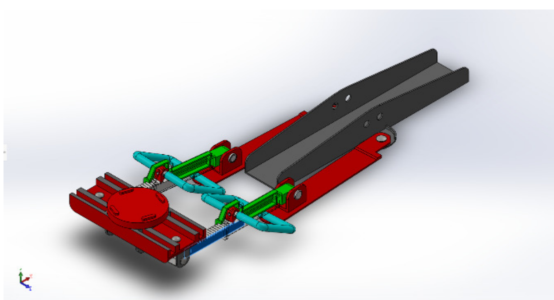

Fig. 13 Assembled view of folded safety system

VI. FINITE ELEMENT ANALYSIS

1. Analysis of safety system using automatic reverse locking rack mechanism for car jack: The analysis of the safety system using automatic reverse locking rack mechanism model is carried out using ANSYS workbench software using finite element method. The analysis is done in the static structural method. Then the feed the material data. Import the geometry model in IGES format. Specify the materials for each component used in the model. Mesh the model. Apply the boundary condition such as fixed support is assigned to the bottom plate; by assigning the fixed support to the bottom plate is constrained in all degree of freedom and it would withstand the load acting on it. Then apply 87332.670 pascal pressure which acts on the rotatory support. Solve the model for the solution of total deformation, equivalent stress(von-Mises), maximum principal stress, maximum shear stress, and equivalent elastic strain.

The figure 14, 15, 16, 17 and 18 shows the analysis for safety system using automatic reverse locking rack mechanism for car jack.

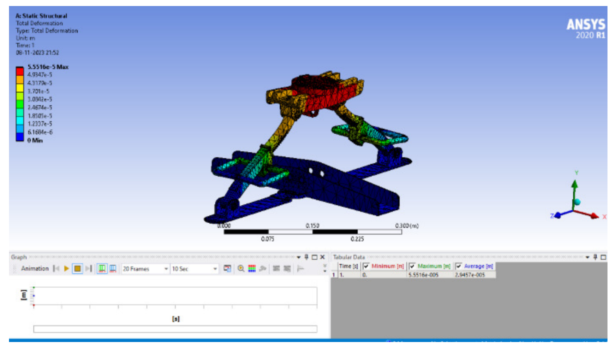

Fig. 14 Total deformation for safety system

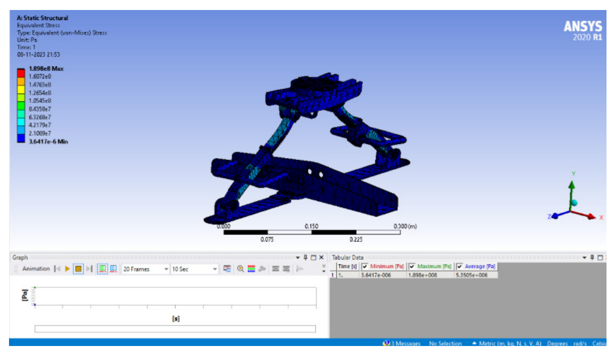

Fig. 15 Equivalent stress for safety system

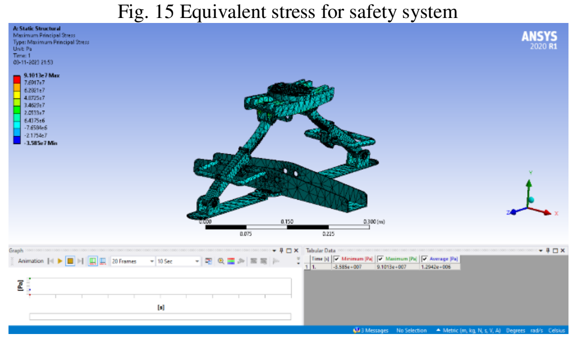

Fig. 16 Maximum principal stress for safety system

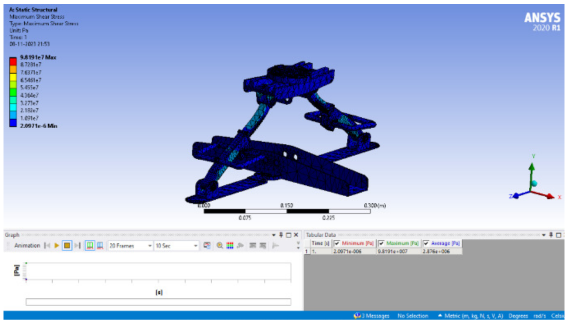

Fig. 17 Maximum shear stress for safety system

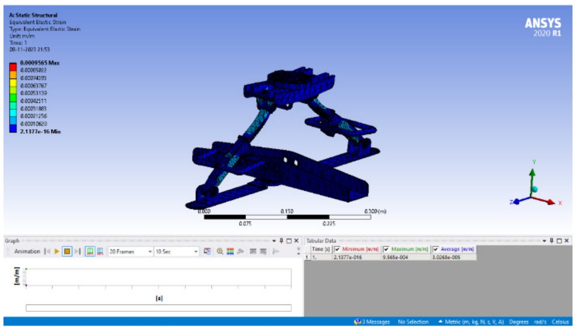

Fig. 18 Equivalent elastic strain for safety system

2. Analysis of automatic reverse locking rack mechanism: The analysis of the automatic reverse locking rack mechanism model is carried out using ANSYS workbench software using finite element method. The analysis is done in the static structural method. Then the material data can be obtained using material library or else give the corresponding property values manually. Import the geometry model in IGES format. Specify the materials for each component used in the model. Mesh the model. Apply the boundary condition such as fixed support is assigned to the bottom slot; by assigning the fixed support to the bottom slot is constrained in all degree of freedom and it would withstand the load acting on it. Using probe got the pressure which acts on the rack's head. Then apply 1.1534E^{7} pascal pressure which acts on the rack type ratchets head. Solve the model for the solution of total deformation, equivalent stress(von-Mises), shear stress, etc. The Fig. 19, 20 and 21 shows the analysis for automatic reverse locking rack mechanism.

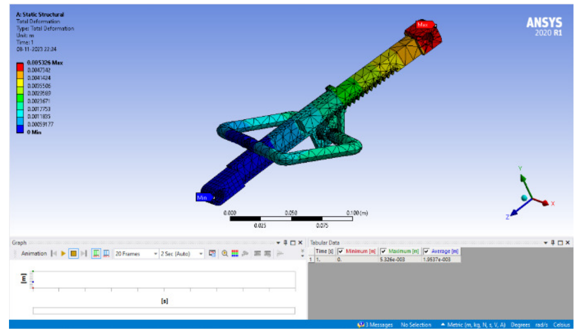

Fig. 19 Total deformation of automatic reverse locking rack mechanism

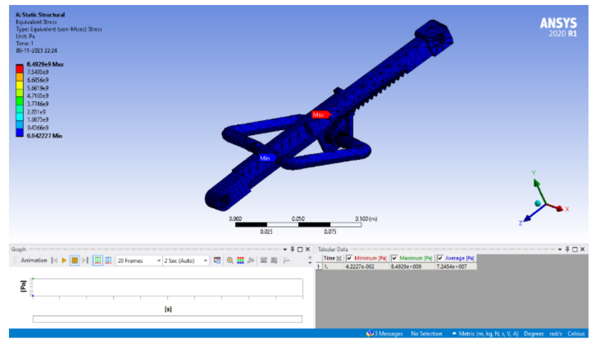

Fig. 20 Equivalent stress for automatic reverse locking rack mechanism

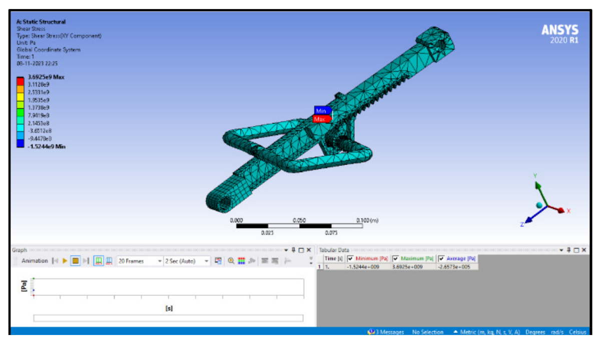

Fig. 21 Shear stress for automatic reverse locking rack mechanism

VII. RESULTS AND DISCUSSION

It is observed that the total deformation, equivalent stress (von-mises stress), maximum principal stress, maximum shear stress and equivalent elastic strain for the safety system is obtained. The maximum stress is occurring at the top plate where it makes contact with the rack type ratchet.

The Table2 shows the results obtained for the safety system using automatic reverse locking rack mechanism for car jack.

Input parameter:

Load = 450 x 9.81 = 4414.5 N

Area = $(3.141/4) \times (80 \times 10^{-3})^2 = 0.005026\ m^2$

Pressure = $4414.5 / 0.005026 = 878332.67\ N/m^2$

TABLE II
RESULTS OBTAINED FOR SAFETY SYSTEM

	Range	Values
Total deformation [m]	**Maximum**	5.551e-5
	Minimum	0
Equivalent stress [pa]	**Maximum**	1.898e+8
	Minimum	3.641e-6
Maximum principal stress [pa]	**Maximum**	9.101e+7
	Minimum	-3.585e+7
Maximum shear stress [pa]	**Maximum**	9.819e+7
	Minimum	2.097e-6
Equivalent elastic strain [m/m]	**Maximum**	9.565e-4
	Minimum	2.137e-16

It is observed that the total deformation, equivalent stress (von-mises stress) and Shear stress for the automatic reverse locking rack mechanism is obtained.The Table3 shows the results obtained for automatic reverse locking rack mechanism. The maximum stress occurs at the contact point of rack type ratchet's tooth with the pawl.

TABLE III
RESULTS OBTAINED FOR AUTOMATIC REVERSE LOCKING RACK MECHANISM

Total deformation [m]		**Equivalent stress [pa]**		**Shear stress [pa]**	
Max	**Min**	**Max**	**Min**	**Max**	**Min**
3.463 e-10	0	552.25	2.304 e-9	240.1	-99.126

VIII. CONCLUSION

From finite element analysis of the safety system using automatic reverse locking rack mechanism for car jack the following conclusions can be drawn.

- Total deformation of the model is less under loading condition.
- Overall, the model of the safety system using automatic reverse locking rack mechanism for car jack gives nearly maximum stress with minimum deformation value in static structural analysis.
- Hence it can withstand the vehicle load even when the car jack fails its function.
- Also, it can be used for the supporting system of the car jack.

REFERENCES

[1] Patil, M.R. and Kachave, S.D.,"Design and analysis of scissor jack"International Journal of Mechanical Engineering and Robotics Research, 4(1), pp.327-335, 2015.

[2] Venkatesh, R., Karunakaran, V., Raj, A.A.S., Kanna, R.D. and Rahman, H.M.S., "Design and structural analysis of inbuilt car jack system"*Materials Today: Proceedings, 46, pp.9933-9937, 2021.*

[3] Chitransh, J. and Hussain, D., "Designing and Calculating the Stresses Induced in Scissors Jack for Three Different Materials" International Journal of Scientific & Technology Research, 5(07), pp.119-123, 2016.

[4] Patil, H.M. and Chandak, P.A., "Stress analysis of ratchet pawl design in hoist using finite element analysis," International Journal of Engineering Research and General Science, 3(4), 2015.

[5] . Bondaletov, V.P., "Pawl motion in free-running ratchet gear at high ratchet speeds," Russian Engineering Research, 29(1), pp.10-11, 2009.

[6] Kennedy, J.A., Howell, L.L. and Franklin, T.N., "The Ratchet and Pawl Ring (RaPR) Mechanism" In 12th IFToMM World Congress, Besançon,(France), 2007.

[7] Bondaletov, V., Medvedev, V. and Petrov, A., "Extending the life of free-wheel ratchet mechanisms by backup of the working components" Russian Engineering Research, 30(12)., 2010.

[8] Arunkumar, A., Muthumani, T. and Balasubramani, V., 2015. Design and fabrication of anti-roll back system in vehicles using ratchet and pawl mechanism. Int J Emerg Technol Comput Sci Electron, 12, pp.1-4.

[9] Lakshya Shrivastava, et al (2018), Research on designing of automatic reverse wheel locking mechanism, International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 04 | Apr-2018.

[10] S.S. Dheeban Kumar, et al (2018), Design and fabrication of rack and pinion jack, International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 10 | Oct 2018.

