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TOPOLOGY OPTIMIZATION OF AN ALLOYWHEEL RIM FOR LIGHT WEIGHT VEHICLE

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Abstract

India is a rapidly rising country and a major player in the global automobile sector. There has to be a greater emphasis on product creation since competition for automotive parts and components is too intense. Low manufacturing cost, excellent performance, and improved quality are needs and demands that must be addressed in product development right from the conceptual design phase. The design, development, analysis, and optimisation of an alloy wheel taking various materials into consideration are the main foci of this project. We used SOLIDWORKS for the conceptual sketching, design, and modelling of the wheel spokes. For topology optimisation, five bolt wheels were selected after considering the manufacturing process and stress distribution. Using the fusion 360 program Weight reduction without sacrificing functionality is achieved with the use of a topology optimisation approach based on the ESO approach. The ESO METHOD employs a shape-cutting operation on the evolutionary model before subjecting the resulting output to further analysis. After analysing the final model wheel rim according to SEA requirements, it was found that the stresses created by the optimised rim are much lower than the material's yield stress, making it safe to use. Optimal topology removes 26% of the material. Through the use of finite element analysis, we were able to evaluate the rigidity and strength of the wheel's construction. This should allow us to achieve the standards set by wheel topology optimisation while also reducing the wheel's weight.

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1.1 Introduction

In the automotive industry, alloy wheels are wheels that are made from an alloy of Aluminum or magnesium. Alloys are mixtures of a metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of Aluminum or magnesium are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. Although steel, the most common material used in wheel production, is an alloy of iron and carbon, the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys.

The earliest light-alloy wheels were made of magnesium alloys. Although they lost favor on common vehicles, they remained popular through the 1960s, albeit in very limited numbers. In the mid-to-late 1960s, Aluminum-casting refinements allowed the manufacture of safer wheels that were not as brittle. Until this time, most Aluminum wheels suffered from low ductility, usually ranging from 2-3% elongation. Because light-alloy wheels at the time were often made of magnesium (often referred to as "mags"), these early wheel failures were later attributed to magnesium's low ductility, when in many instances these wheels were poorly cast Aluminum alloy wheels. Once these Aluminum casting improvements were more widely adopted, the Aluminum wheel took the place of magnesium as low cost, high-performance wheels for motorsports.

1.2 wheel rim assembly

A safety tire and wheel assembly which includes an improved multiple-piece wheel rim assembly (10 or 100) for preventing inflation and/or venting to atmosphere when the rim assembly components are improperly assembled, and an improved safety insert (14) mounted on the wheel rim base for supporting the tire tread during operation following loss of inflation pressure.

1.3 History of wheel rim

Researchers agreed that 3500 BC is the year when the wheel was invented, which is more of a ballpark than an exact year. The place is Mesopotamia, the area now occupied by war-ravaged Iraq. The first wheel for transportation purposes is approximated to 3200 BC, its purpose being to move the Mesopotamian chariots. To be completely historic, as noted here, the very beginning of the wheel goes back to the Paleolithic era (15,000 to 750,000 years ago).

Back then, humans used logs to move large loads around. The main problem with this method of transportation was that many rollers were required, and care was required to insure that the rollers

stayed true to their course. One theory as to how this obstacle was overcome suggests a platform, or sledge, was built with cross-bars fitted to the underside, thereby preventing the rollers from slipping out from under the load.

It's fair to start talking about automobile wheels starting with Karl Benz's 1885 Benz Patent Motorwagen. The three-wheel vehicle used bicycle-like wire wheels, which were fitted with hard rubber. Speaking of rubber, the first people who thought about using it for automobile purposes were André and Edouard Michelin, who later founded the famous tire company. In 1910, the B.F. Goodrich Company invented longer life tires by adding carbon to the rubber.

Fig. First designed wheel rim

Overseas, Ford's Model T used wooden artillery wheels, which were followed in 1926 and 1927 by steel welded-spoke wheels. Unlike Karl Benz's first vehicle, the car that "put America on wheels" had pneumatic tires invented by Mr. Dunlop. There was, however, a big difference between those tires and the ones we used today. Made of white carbonless rubber, the tire had a life expectancy of around 2000 miles. A tire only lasted for around 30 or 40 miles before it needed repairs. Common problems included: the tire coming off the wheel, punctures and the tube being pinched.

Dongying ju did Topology optimization on wheel and structural analysis to reduce weight, Not used any fillet parts after optimization, A.rashwan designed wheel rim using topology optimization, he not considered Aluminum alloys, venkateshwara rao et al. Design & optimization of a rim using finite element analysis. The objective is to design a alloy wheel using ESO method using solid works software and to optimize and reduce the weight of wheel using topology optimization.

2. Topology Optimization

Topology optimization is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. Topology optimization is different from shape optimization and sizing optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations. The conventional Topology optimization formulation uses a finite element method (FEM) to evaluate the design performance. The design is optimized using either gradient-based mathematical programming techniques such as the optimality criteria algorithm and the method of moving asymptotes or non gradient-based algorithms such as genetic algorithms.

Topology Optimization has a wide range of applications in aerospace, mechanical, bio-chemical and civil engineering. Currently, engineers mostly use Topology optimization at the concept level of a design process. Due to the free forms that naturally occur, the result is often difficult to manufacture. For that reason the result emerging from Topology optimization is often fine-tuned for manufacturability. Adding constraints to the formulation in order to increase the manufacturability is an active field of research. In some cases results from Topology optimization can be directly manufactured using additive manufacturing; Topology optimization is thus a key part of design for additive manufacturing.

Topology optimization has been used by mechanical and civil engineers for many years, for example in order to minimize the amount of used material and the strain energy of structures while maintaining their mechanical strength. Topology optimization is a mathematical method which spatially optimizes the distribution of material within a defined domain, by fulfilling given constraints previously established and minimizing a predefined cost function. For such an optimization procedure, the three main elements are design variables, the cost function and the constraints. The traditional solutions for structural optimization problems in buildings were

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determined by the use of direct search methods on an Isotropic Solid and Empty (ISE) topology. In an ISE topology, the elements are either filled by a given isotropic material or do not contain any material. However, due to the large number of elements, the application of direct search methods on an ISE topology was found to be computationally extremely expensive. Therefore, since the 1980s, the main focus in this area has been to develop more efficient methods to obtain faster solutions.

3. Design of alloy wheel rim

- We have designed wheel rim using following drafting.
- The below figure is the reference we have taken for our model to design.
- The reference figure belongs to the Toyota matrix car.

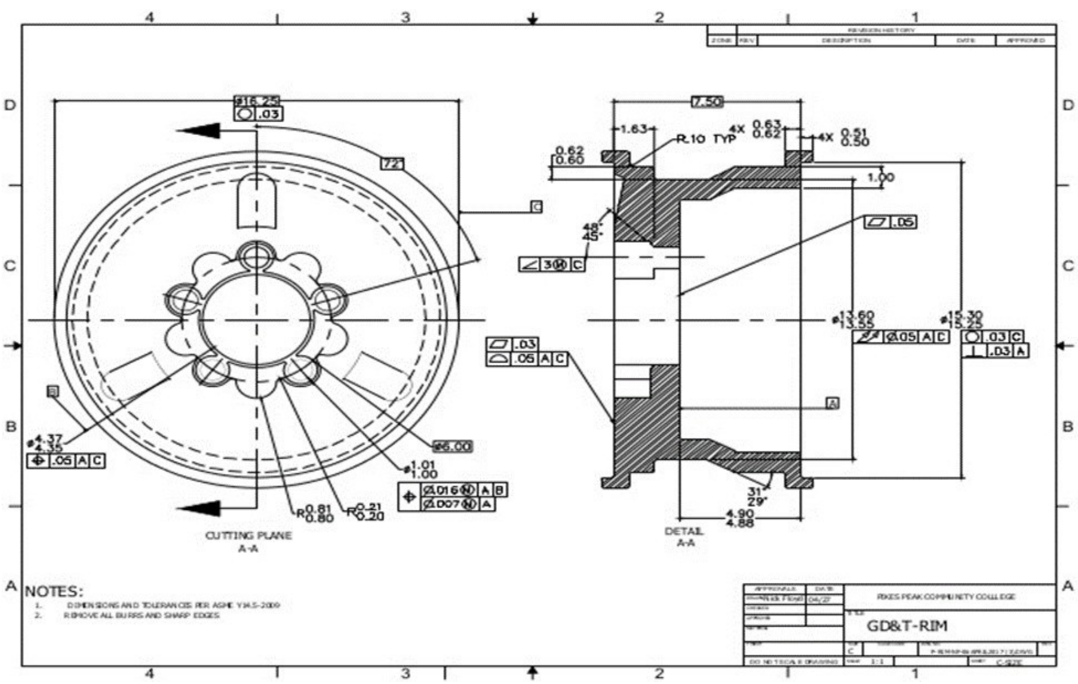

Fig.3.1 Existing wheel rim drafting

- Design a simple, good and rigid wheel rim. So, without wasting our time lets start designing wheel rim.
- Open SOLIDWORKS, go to File > New.
- Select the Part icon and click ok.
- Now before starting drawing, we need to assign units. We are going to design a wheel rim in MMGs system.
- Click on the Options at the top of the screen.
- Check the units is in MMGs system or not and click OK.
- Start a new sketch on Front Plane.

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- Draw a set of construction lines creating a square and draw a vertical middle construction line as shown and give dimensions.
- Exit the sketch..

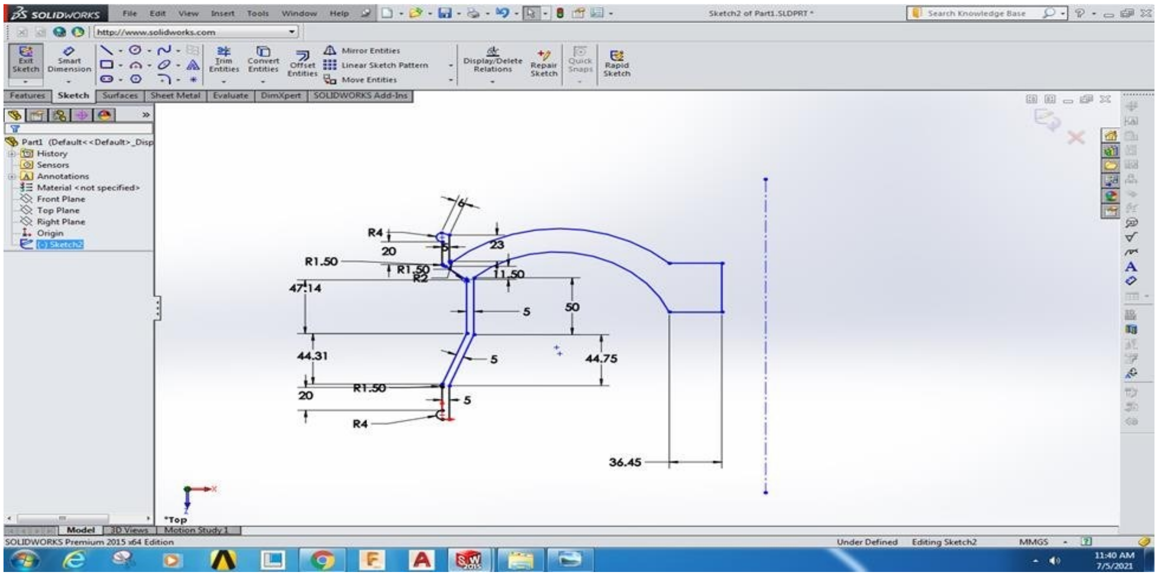

Fig.3.2 Sketch of wheel rim

- This is the sketch which we have achieved from the reference diagram which was drawn on the right side face.
- Click on the Revolved Boss/Base tool in the Features ribbon.
- Select the middle construction line of the sketch as the Axis of Revolution and Validate

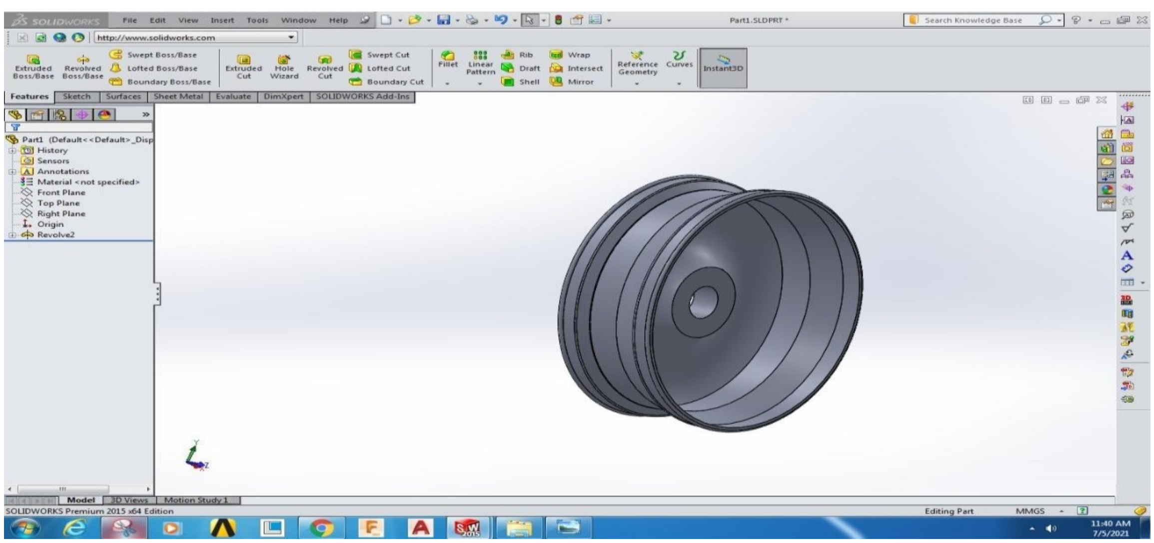

Figure 3.3: isometric view of model

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4. Topology Optimization

Step 1 : Importing file from solid works to fusion 360

OPEN > UPLOAD > FILES > SELECT FILE > OK

Step 2 : open design module then change it into simulation module and select shape optimization module.

DESIGN > SIMULATION > SHAPE OPTIMISATION

Step 3 : Applying Constraints

CONSTRAINS > FIXEDCONSTRAIN>SELECT FACES

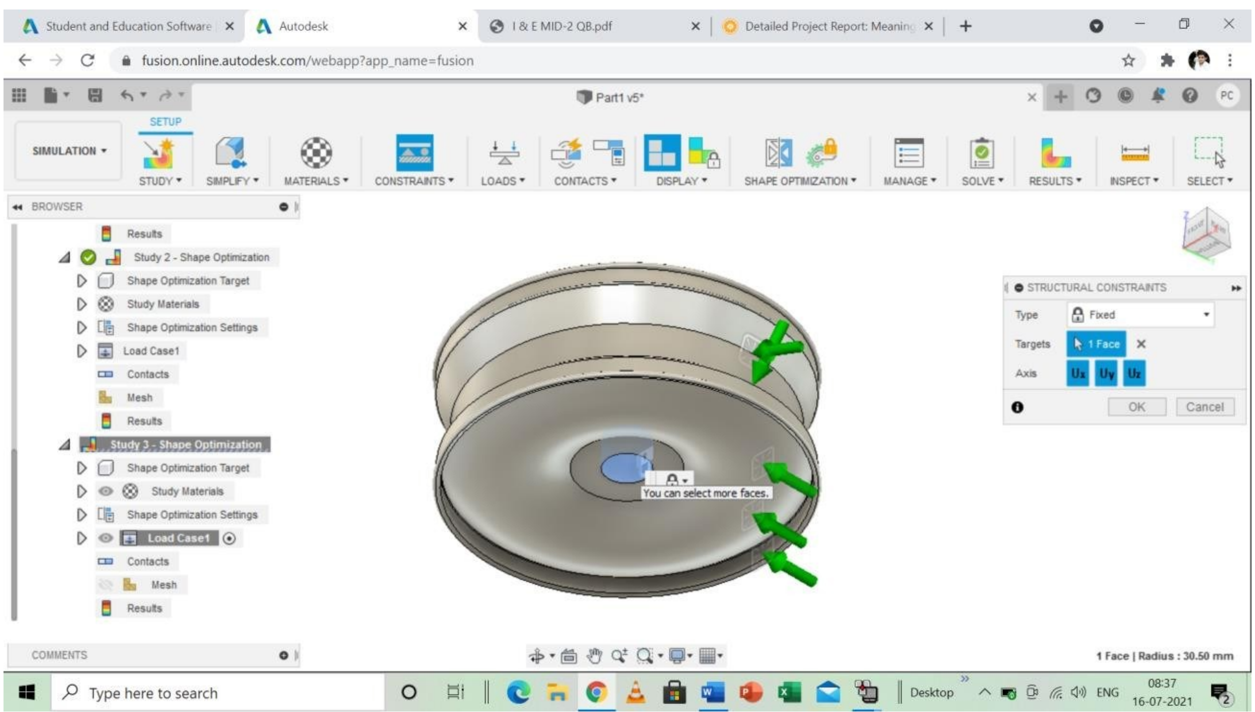

Fig 4.1. Constrains of 6 faces

Step 4 : Applying pressure case

LOAD > PRESSURE > SELECT FACES

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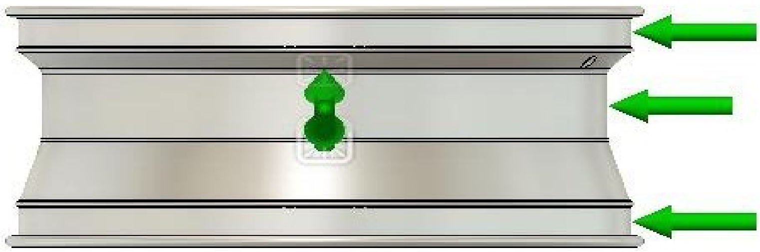

Fig 4.2. Pressure applied faces

Step 5: Meshing

MESH > ABSOLUTE SIZE > RIGHT CLICK > GENERATE MESH

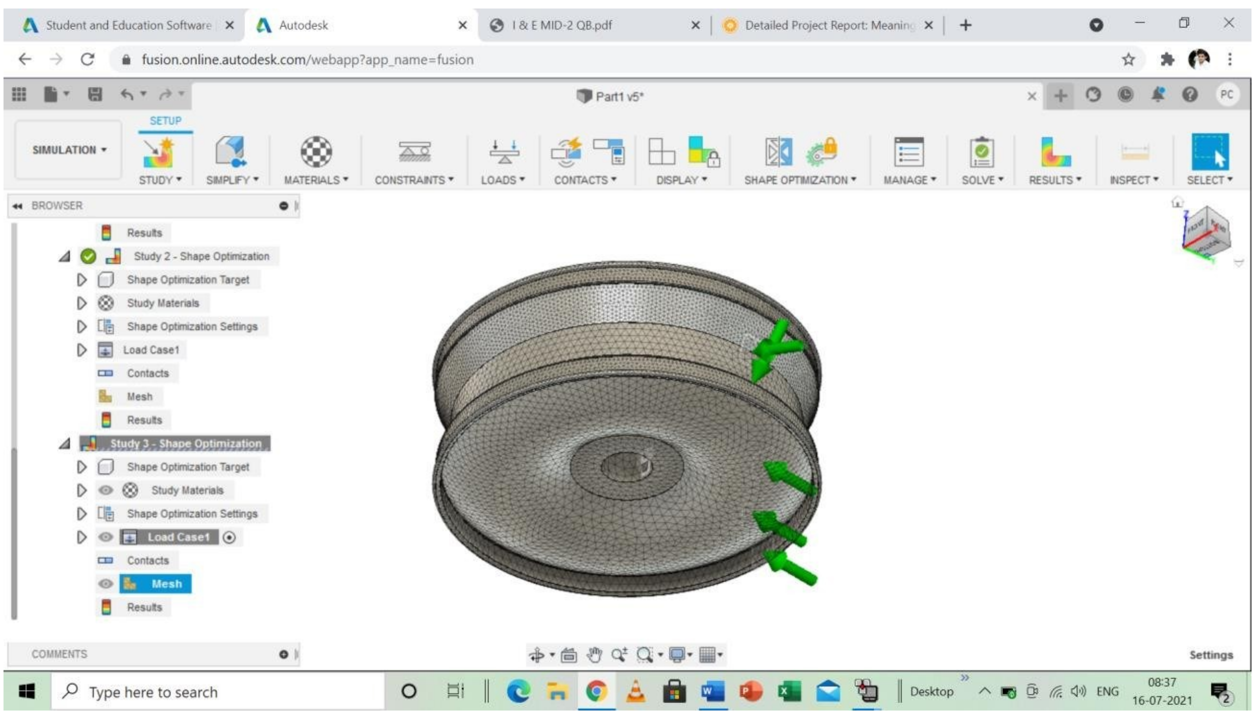

Fig 4.3. Meshing of model

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STEP 6 : SOLVE

PRESOLVE CHECK > SOLVE > SOLVE STUDY

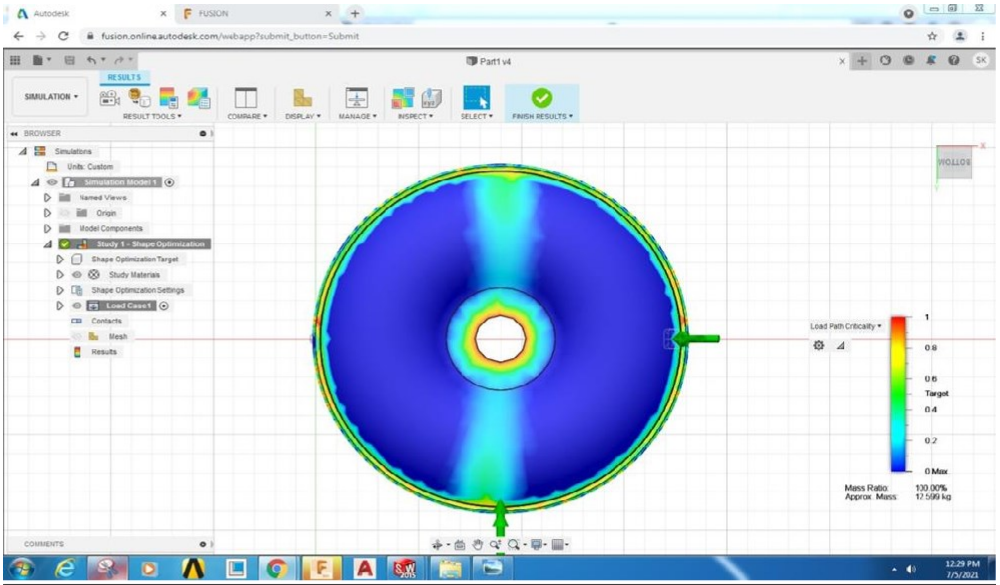

Fig 4.4. Topology optimization

SHAPE CUTTING OPERATION

After we have successfully performed shape optimization, now we have to perform shape cutting operation. The most reliable method is used for design and performed the shape cutting operation i.e., as following.

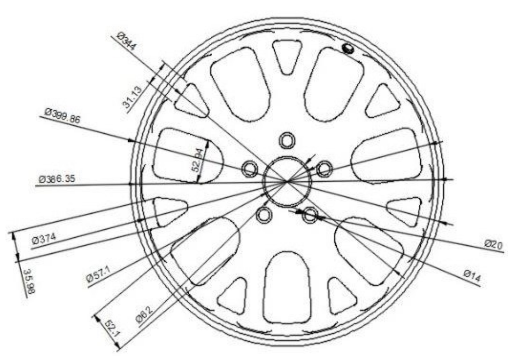

Fig 4.5. Drafting of wheel front face

- We converted 127 sharp edges chamfer edges i.e., as following figure.

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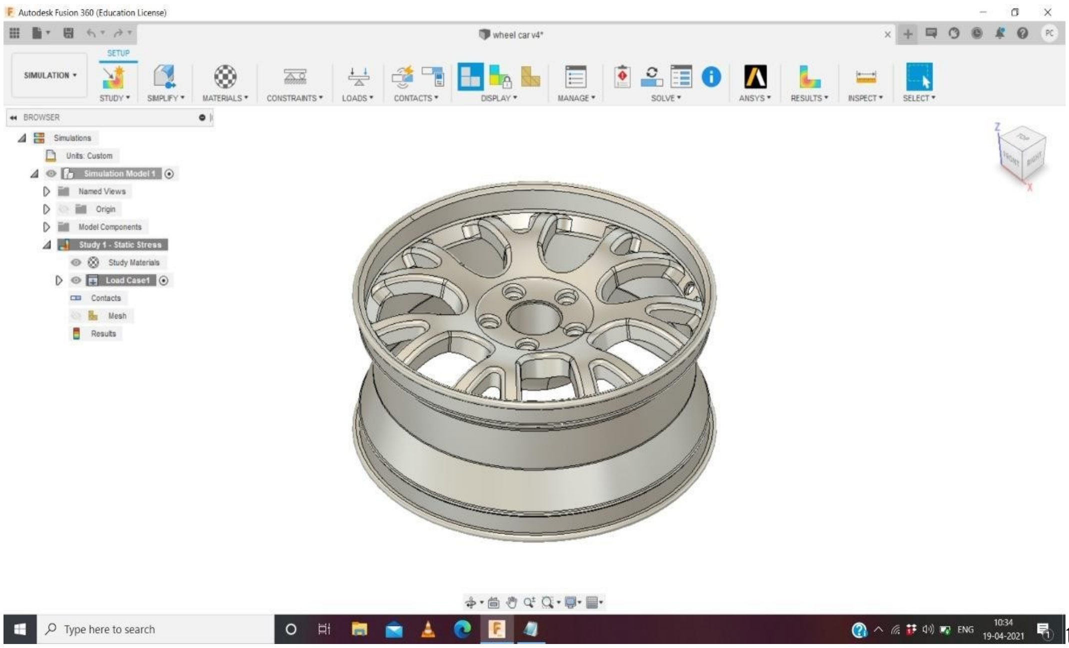
- 

to

- Fig.4.6 Chamfered final model

Comparison of alloy wheel mass before and after optimization

Mass of alloy wheel rim before optimization (Kg)	Mass of alloy wheel rim after optimization (Kg)	Reduction in percentage of mass %
12.599	9.24	26%

STRESS

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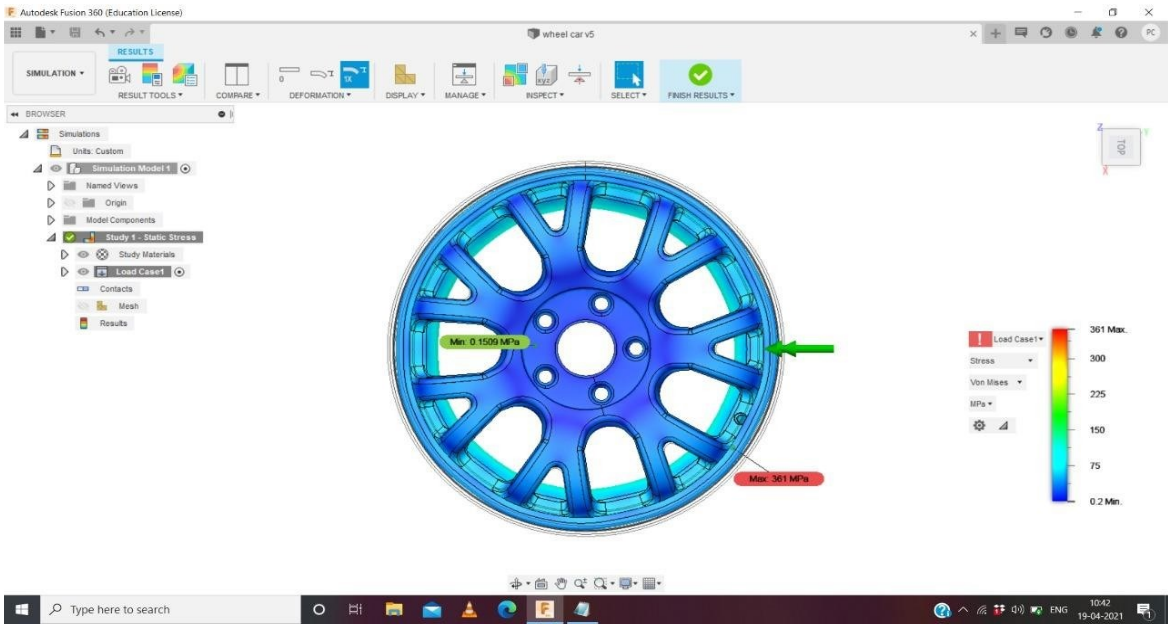

Fig 4.6. Stress of AL 1100-H14

The minimum stress is 0.1509mpa The maximum stress is 361mpa, We Can observe the direction of stress .

Displacement

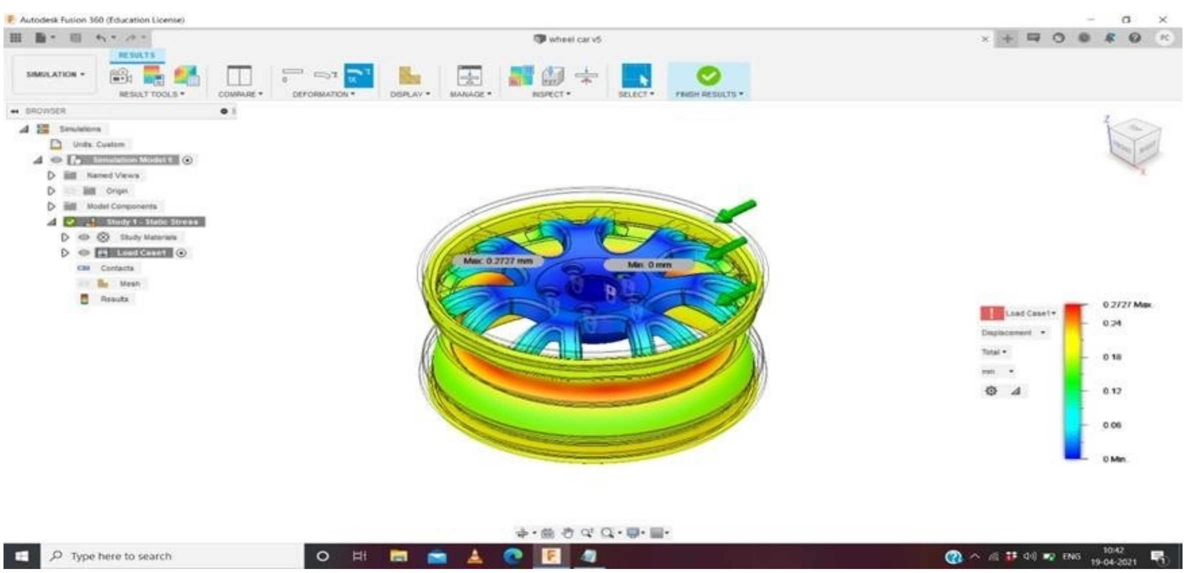

Fig 4.7 Displacemnt of AL 1100-H14

There is some displacement in rim The maximum displacement is 0.2727mm Minimum is 0mm

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We can also observed deformation on the surface.

Reaction forces

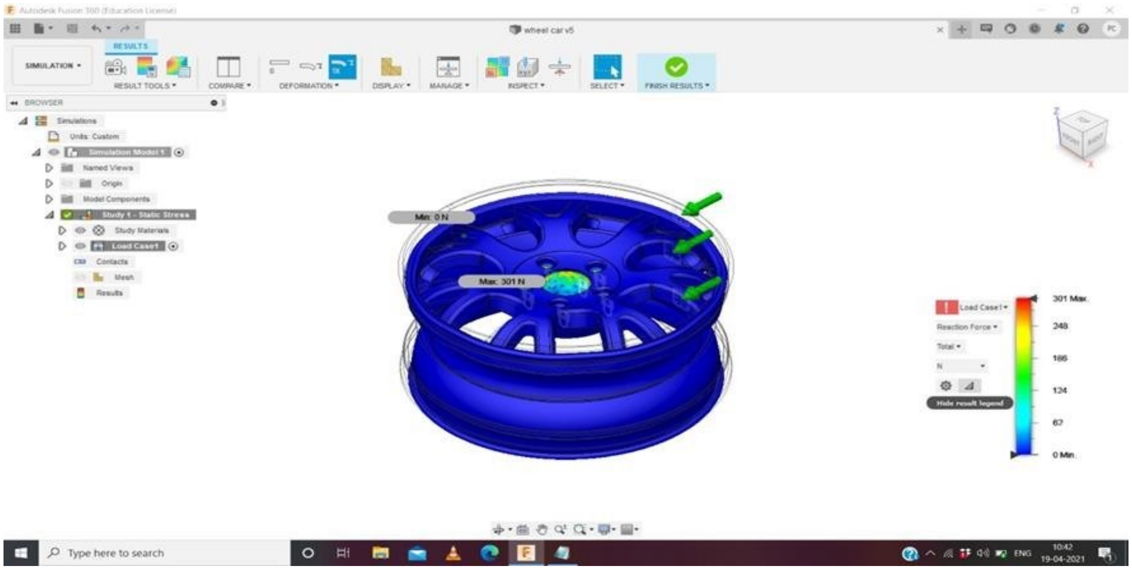

Fig 4.8. Reaction forces of AL 1100-H14

The reaction forces are developed at center of the rim Minimum developed reaction force is 0N Maximum is 301N

COMPARISON OF ALLOY WHEEL RESULTS AFTER OPTIMIZATION :

PROPERTIES	AL1100 H14		AL6061 T6		AL 7075	
	MAX	MIN	MAX	MIN	MAX	MIN
FACTOR OF SAFETY	15	0.2674	15	1.039	15	0.637
STRESS	361	O.1509	264.7	0.09572	227	0.00443
DISPLACEMENT	0.2727	0	0.3431	0	0.4636	0
REACTION FORCES	301	0	357.9	0	160.4	0
STRAIN	0.00819	$2.296E^{-6}$	0.006547	$1.745E^{-6}$	0.005366	$9.26E^{-6}$

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CONCLUSION

The model's topology was optimised using Fusion 360, and further shape cutting procedures were carried out. We analysed and optimised the loading and form using Fusion 360 after selecting several materials based on the literature.The findings of the investigation suggest that, when compared to other commonly used aluminium and magnesium alloys, both forged 6061 T6 and other similar alloys have passed the safety factor. The model's topology was optimised using Fusion 360, and further shape cutting procedures were carried out. After analysing the FOS data, the design was optimised using Ansys' optimisation platform, resulting in a weight reduction from 12.599 kg to 9.24 kg. As a result of effectively using design, modelling, analysis, and optimisation techniques, we have successfully finished our design project.

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