Finite Element Analysis for Improved All-Terrain Vehicle Component Design

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Finite Element Analysis for Improved All-Terrain Vehicle Component Design

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Abstract: All-terrain vehicle (ATV) is an off-road vehicle that can be easily driven over any terrain. However, because to the severe stresses imposed by the gravel tracks and the weight limits, one critical component such as the Reduction Gearbox is prone to failure. The gearbox is an expensive component, and if it fails, the vehicle becomes immobilized. Therefore, the aim of the present work is to design, develop and analyze the ATV components for enhancement in life. These analytical designs have been validated using CAD models with FEA tools. Various Analyses like Structural, Repeated loads and Finite Element Analysis (FEA) has been performed to study the behaviour of components and oil flow during operations. The results shows that all the components are not prone to fail within the specified operating limits based on the analytical calculations and Finite Element Analysis.

Keywords: ANSYS; CFD; Finite Element Analysis; Gearbox

1. Introduction

In recent years, technological progress has paved the path for inventive solutions across various domains, including transportation and mobility. One of the notable outcomes of this progress has been the emergence of All-Terrain Vehicles (ATVs) as versatile and indispensable means of traversing a diverse range of challenging terrains, spanning from rugged off-road trails to urban streets. These ATVs find applications across a spectrum of fields, encompassing recreational use, agricultural operations, military deployments, and even disaster relief missions. The efficacy and dependability of these vehicles hinge significantly upon the intricate design and development of their constituent components, which play a pivotal role in ensuring both safety and performance.

This research endeavor delves into the realm of ATV engineering, with a specific focus on the complex process involved in conceiving and maturing the components that constitute these resilient and multifaceted vehicles. The evolutionary journey of ATVs from their rudimentary origins to the present sophisticated machines, equipped with advanced features, stands as a testament to the relentless pursuit of innovation and the enduring commitment to excellence in the field of automotive engineering.

The escalating demand for ATVs across diverse sectors underscores the growing importance of addressing the multifaceted challenges associated with the design and development of these critical components. These challenges encompass a spectrum of considerations, including the assurance of structural integrity, optimization of power delivery mechanisms, enhancement of safety features, and the imperative to minimize environmental footprints. In response to these demands, engineers and researchers have embarked on a transformative journey of innovation, exploring novel materials, pioneering manufacturing techniques, and redefining design paradigms.

This paper aspires to offer a comprehensive exposition of the intricate intricacies underlying the design and development of ATV components. The endeavor encompasses an exploration of contemporary trends, emergent technologies, and state-of-the-art research that collectively shape the trajectory of ATV engineering. Additionally, the inclusion of pertinent case studies and practical illustrations will serve to vividly demonstrate the real-world applicability of the principles discussed herein.

The significance of this research transcends academic boundaries, as it not only augments the knowledge base of automotive engineering but also holds the potential to instigate a paradigm shift in our perceptions and applications of All-Terrain Vehicles. By meticulously addressing the multifarious challenges and opportunities inherent in ATV component design and development, we stand poised to chart a course toward the creation of safer, more efficient, and ecologically responsible vehicles capable of excelling across a spectrum of terrains and applications. Through synergistic collaboration between academia and industry stakeholders, the capacity enhanced to push the boundaries of innovation, thereby unlocking novel possibilities for the future of mobility[1).

2. Literature Review

The Honda ATC90, a modern all-terrain vehicle (ATV) commonly referred to as a quad, was released in the early 1970s[2)]. All Terrain Vehicles (ATVs) are increasingly being used around the world for both work and recreational use. ATVs are becoming heavier and quicker over time[3), 4)]. Dry weights range between 200 and 1000 pounds, and some types are capable of exceeding speed of 75 mph. ATV engineering and vehicle design are critical components of injury prevention. ATVs can become unstable due to their intrinsic vehicle design, causing the vehicle to roll over and potentially inflicting catastrophic harm to the rider. All-terrain vehicles, motorbikes, and snowmobiles are among the key markets for continuous variable transmissions (CVT)[5)]. Several studies have found that ATV rollover rates in incidents involving these vehicles may reach up to 70%[6)]. Serious injuries and fatalities from ATV use are an increasing worry for public health and accident prevention specialists due to their growing popularity and the availability of heavier and even more powerful machines on the market. Any surface or terrain may be traversed with an all-terrain vehicle (ATV). It is designed specifically for rough driving situations. An ATV has several features, including soft suspension springs as well as high ground clearance. It is quite popular to employ a four-wheel-drive (4WD) gearbox in a light ATV. The ATV's ability to travel off-road is improved by having power on all four tyres. The Society of Automotive Engineers sponsors the BAJA SAE student-level ATV design competition (SAE). The goal of this event is for students to design, evaluate, and build lightweight ATVs. The ATV model is shown in figure 1. Vehicles are evaluated in terms of performance, safety, and durability. BAJA ATVs have traditionally preferred its 2WD. This is due to the vehicle being lighter[7)]. Mark Allen discusses a hybrid gearbox that consists of a Salsbury-style rubber belt CVT with a two-speed manual transmission[8)]. By securing the chosen gear pair to the transmission's output shaft, the user may choose the gear ratio that best suits their needs. For maximum speed, the highest gear is used, with engine power, speed, and fuel consumption serving as limits. To get maximum speed on highest inclines, lower gears are chosen. Additionally, the lower ratios are built to enable crawl speeds to reduce the need for clutches and brakes in city traffic. To provide more seamless gear changes, the mid-gear option has been modified by Jaideep Singh[9)].

The reducer's gears and shafts are subject to a variety of forces. A two-stage reducer has four gears and three shafts (two drive gears and two driven gears). The input shaft for the continuously variable transmission has the first reduction drive gear, which is likely the smallest gear among the reduction gears (CVT). The compound gear, is also known as the second shaft or intermediate shaft. It is made up of the driven gear from the first reduction stage and the driving gear from the second reduction stage. The driven gear of his second reduction stage; possibly the biggest gear is found on his third shaft, which is referred to as the output shaft. Through a limited slip differential (LSD), which is connected to the gearbox output shaft via a chain drive, this output shaft transmits the necessary speed to the wheels. The first reduction stage's drive gear begins to revolve in a certain direction after receiving a predetermined number of revolutions, applying torque to the driven gear. This occurs as a result of the gears' teeth meshing with one another and the driving gear's teeth pulling on the gear's teeth (driver gear). In this instance, the input gear of the second reduction stage is linked to the output gear of the first reduction stage. Therefore all such parameters are required for precise calculations and design of gear box. Hence the present work focused on design, develop and analyze the ATV gearbox for enhancement in life. These analytical designs have been validated using CAD models and FEA tools. Various analyses like Structural, Repeated loads and Computational Fluid Dynamics (CFD) has been performed to study the behavior of components and oil flow during operations.

To raise or reduce speed or torque, gearboxes are employed. The gearbox was created with BAJA SAE ATVs in mind. To create, examine the issues with ATVs, and eliminate all of their flaws. Weight, bulk, and expense are the biggest downsides. Regular maintenance and occasional malfunctions were noted. Housing, gear, and shaft research and material selection are part of the construction designs. The choice of gear oil is also made based on market research and fluid behaviour at particular temperatures. The computation for the minimal dimension is performed after the material is chosen. In CAD software, a standard dimension that is similar to the minimal dimension is chosen and modelled. For the components, several profiles were made to assure their structural soundness and lightweight.

Three and four-wheeled powered vehicles known as all-terrain vehicles (ATVs) are designed for usage on a variety of uneven terrain types[10)]. Large low-pressure tires, straddle-style seats, steering handlebars, and motorcycle-style motors are all features of these vehicles[3]. In previous work, some researchers used 10Hp engine to get 19Nm torque. The torque is insufficient in this situation, thus a reduction gear was employed to boost the torque and slow down. To provide flexible gear ratio changes, a CVT was employed. To enhance torque at low rpm and rev at maximum revs, it makes use of a CVT that is built into the transmission[11]. Further, ATV vehicle dynamics were studied by some scientists. By creating an ideal transmission system in accordance with the other subsystems of brakes and suspension, the design and development of optimum efficiency in the vertical axis of ATV vehicle dynamics was accomplished. MATLAB was used to determine the design parameters for the gearbox, braking, and suspension systems. All components underwent 3D computer-aided design, simulation, and verification using Solidworks, ANSYS, and MATLAB, respectively. The off-road vehicle achieves the ideal gear ratio taking into account factors such as maximum speed and acceleration to maximize the effectiveness of the longitudinal dynamics. This is done by taking into consideration the optimal design parameters of the suspension, braking, and transmission systems [12].

ATVs have been utilized in agriculture for a very long time. Despite their enormous contribution to the agricultural sector's productivity, they have been linked to a number of incidents, many of which had negative or tragic outcomes. To help with the creation of efficient treatments, the main goal of their study was to pinpoint risk factors for fatal injuries associated with ATVs[3].

One of the most crucial components of the ATV is the suspension system. All-terrain vehicles that are made expressly for uneven roads depend heavily on their suspension systems. The front and rear suspension components of an ATV are the subject of this study based on design and analysis. It specifically addresses the optimization and modelling of suspension systems. The objective is to reduce track and wheelbase changes, anti-dive, and anti-squat values while maximizing damping. To improve product design for effective weight reduction with enough payloads, failure mode analysis is used. In their study, researchers have chosen suspension parameters based on specified values of camber, toe, wheelbase, track width, and wheel travel in order to improve suspension geometry and further design suspension system components. In the initial step, iterations are carried out to reduce the fluctuation of the suspension parameters throughout wheel travel while the suspension geometry is established based on the underlying assumptions of the suspension parameters. The second stage involves obtaining the spring constants, kinematic ratios, as well as natural frequencies. It's finished choosing the dampers. Making CAD models of the suspension's component parts is the next phase. The design was finalized in the fourth step, which involves certain simulations and optimizations using ANSYS Workbench19[13].

2.1 Design Objective

According to Figure 1, the design objectives and standards have been established to fit BAJA SAE India's high degree of competitiveness. In order to increase interoperability between the power train assembly and the overall vehicle, power train bespoke components are emphasized above original equipment manufacturers (OEMs)[10]. ATVs are made to go swiftly across difficult terrain. The ATV should have good off-road handling and agility. The vehicle must have excellent handling, acceleration, and climbing capability in addition to the capacity to continually drive at high speeds across challenging terrain in potentially hazardous conditions. The driver should be able to quickly switch between his 2WD and his 4WD depending on the terrain.

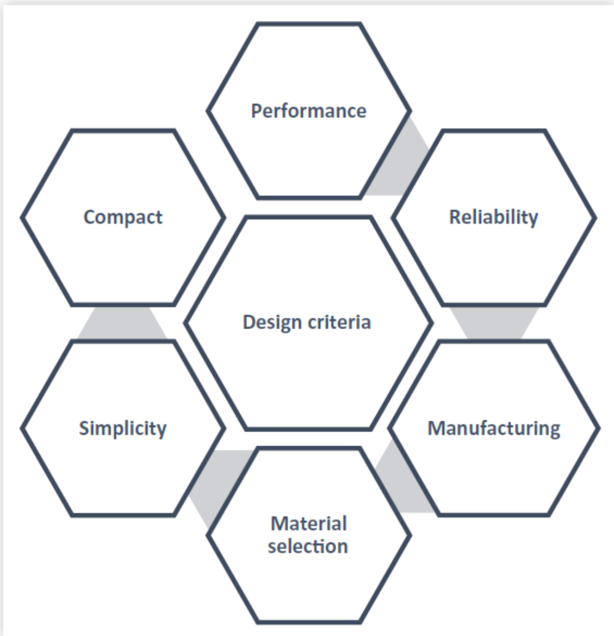

Fig. 1: Criteria for Design of ATV[7]

2.2 Design Considerations

The reducer's gears and shafts are subject to a variety of forces. A two-stage reducer has four gears and three shafts (two drive gears and two driven gears). The input shaft for the continuously variable transmission has the initial reduction drive gear, which is likely the smallest gear in the reduction gear set (CVT). The compound gear, also known as the second shaft or intermediate shaft, is made up of the driven gear from the first reduction stage and the driving gear from the second reduction stage. The driven gear of his second reduction stage, which may be the biggest gear, is located on the third shaft, also known as the output shaft. Through a limited slip differential (LSD), which is connected to the gearbox output shaft through a chain drive, this output shaft transmits the necessary speed to the wheels. Considering all these parameters, calculations are performed to identify the necessary parameters such as loads and torques acting on the components, and to select materials for gears and shafts. Material selection involves various parameters such as weight, cost, machinability and strength[14]. Gear oil is then selected based on heat dissipation and required lubrication.

2.2 Selection of Materials

The choice of materials is critical. The cost of producing gearboxes is mostly comprised of material expenses. There are a lot of inexpensive alloys available on the market. For each gearbox component, the best materials that can endure the aforementioned standards are chosen while taking weight and performance into account. It was determined to utilize only one material for the shafts, another for the gears, and a third for the housing in order to minimize the diversity of materials required.

Although it should be as light as possible, the casing must yet withstand the stress placed on it by the structure. Due to continual vibrations, cast iron becomes brittle and splits. Steel is an excellent alternative, but it still weighs a lot. Therefore, choosing aluminium is a good choice. We chose aluminium alloys with good strength to weight ratios since pure aluminium has lower yield and increased risks of failing. The density of aluminium is 2700 kg/m3. One can choose between aluminium alloys in the six or seven series. After machining, these alloys can be hardened to achieve maximum strength.

2.3 Research Methodology

This study employs a comprehensive research approach that combines both qualitative and quantitative methodologies. This approach integrates theoretical exploration with practical experimentation, aiming to address the multifaceted aspects associated with designing and developing All-Terrain Vehicle (ATV) components. Moreover, the research incorporates a systematic review of the existing body of literature, followed by empirical investigations, to facilitate a thorough understanding of the subject matter.

The research adopts a systematic and structured methodology to investigate the design and development of ATV components through the utilization of Finite Element Analysis (FEA). The primary focus of this study centers on computational analysis and simulation techniques, with the goal of optimizing the performance and durability of these components.

A critical component of this research involves the creation of precise finite element models. Computer-Aided Design (CAD) software is harnessed to generate three-dimensional (3D) models of the ATV components. Subsequently, these CAD models are imported into FEA software for the purpose of mesh generation, setting up boundary conditions, and applying loads.

In terms of material modeling, appropriate material models are carefully chosen and integrated into the FEA software to ensure an accurate representation of the behavior of the materials employed in the components. These models encompass various material properties, including elasticity, plasticity, and other material-specific characteristics.

Meshing, an integral step in the methodology, involves dividing the 3D CAD models into finite elements. This discretization process transforms the geometry into smaller elements that facilitate numerical analysis. To enhance precision, mesh refinement is executed, particularly in regions characterized by high stress or deformation.

The research methodology encompasses the application of realistic boundary conditions to the finite element model, simulating actual operating conditions. This encompasses constraints, loading conditions, and environmental factors such as temperature and vibration.

To comprehensively evaluate the behavior of the ATV components under diverse operational conditions and loads, Finite Element Analysis is conducted. This includes various types of analysis such as static structural analysis, dynamic analysis, thermal analysis, and fatigue analysis, tailored to the specific characteristics of the components under investigation.

In summary, this research methodology outlines a systematic and structured approach to the design and development of ATV components utilizing Finite Element Analysis. By employing CAD modeling, precise material representation, realistic simulations, and optimization techniques, the study aims to produce robust and high-performance ATV components.

3. Modeling of Two stage gear box

The dimensions of the Gears, shafts, and Bearings have been generated based on the dimensions obtained from the analytical calculations. These dimensions have been rounded off to the highest standard-definable value for ease of availability. The components have been modeled in Solid Works based on the dimensions.

3.1 Design of Spur Gear

The spur gear is a typical component in all types of transmission systems because it efficiently transfers motion and power among parallel shafts. The 3D model of gears are given in Figure 2, Figure 3, Figure 4.

3.2 Design of Shaft

A shaft is a rotating component that transfers power and rotary motion. It typically has a circular cross section and can be solid or hollow. The shaft modeled is shown in figure 5 and figure 6 respectively.

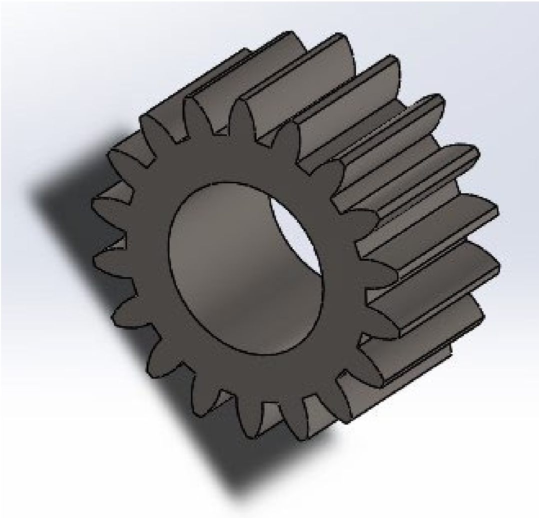

Fig. 2: 1st Spur gear 3D model with 18 teeth

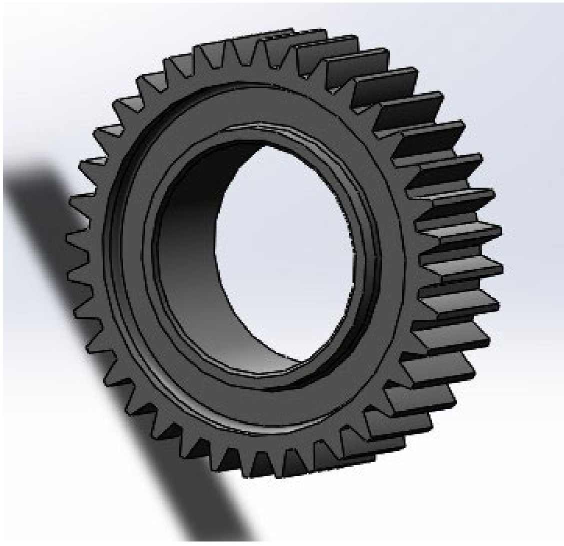

Fig.3: 2nd Spur gear 3D model with 36 teeth

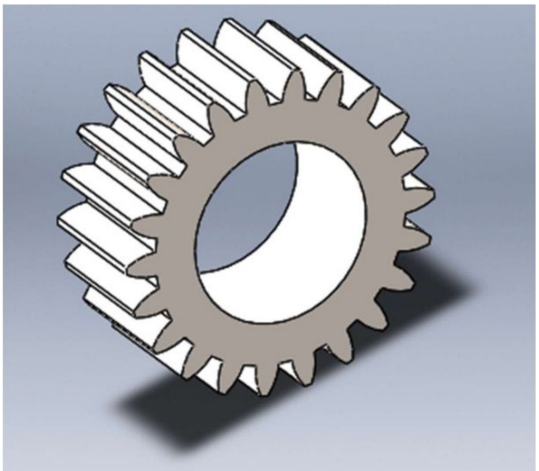

Fig.4:3rd Spur gear with 22 teeth

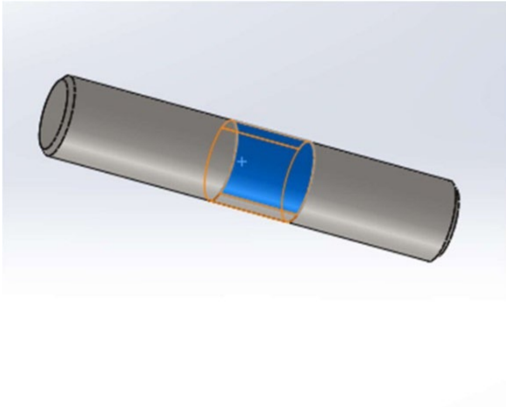

Fig. 5: 3D model of Input shaft

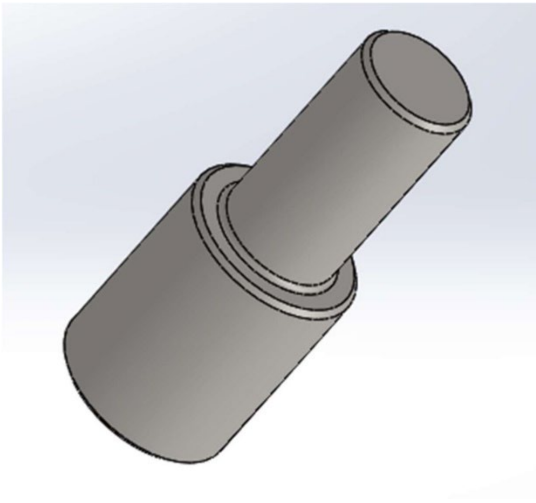

Fig. 6: 3D model of Intermediate shaft

3.3 Design of Gearbox Casing

The gearbox housing should completely enclose the interior of the gearbox without contacting the outside world. In order to stop gear oil from leaking, the housing must be a sealed container. One case cannot be produced in a single step. During maintenance, this is used to open the gearbox. In order to represent the situation, when divided into two sections as illustrated in Figure 7 and Figure 8 respectively. Commercially available M6 nuts and bolts were used to join the two sections together. First, a manual calculation of the overall center-to-center distance between each step was made. These measurements were used to build holes in the housing for the shaft's accommodation and mounting. The housing's interior profile is made to hold in enough oil to keep the working components cool. This profile also contributes to improved internal oil flow. There is a projection for oil injection into the gearbox on the top of the case. A small, thick bracket is added to the end of the outer case profile to accommodate holes for bolts and nuts that fit inside the shaft. It also helps protect the bearings from dust. A 12mm boss is added to the underside of the case and a 10mm hole is drilled. These holes are for attaching the transmission to the ATV's frame. Excess material was removed where I felt the least stress. The case has a smoother shape and is more aesthetically pleasing.

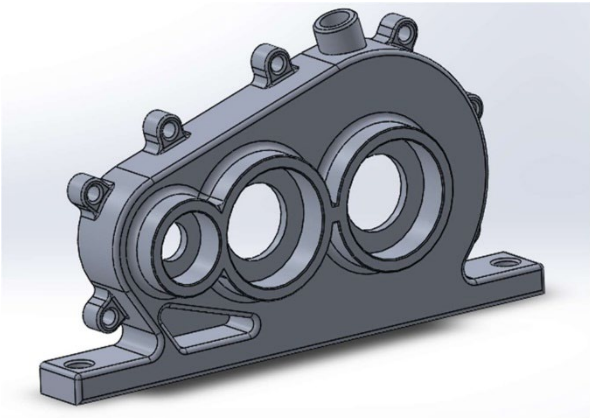

Fig. 7: 3D model of Gearbox Casing – Outer Side

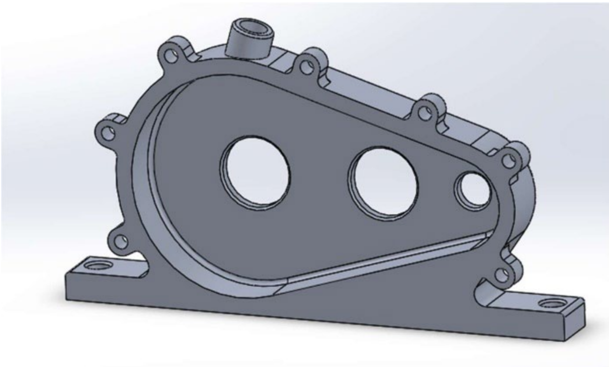

Fig. 8: 3D model of Gearbox Casing – Inner Side

The Solid Works Assembly module is used to put all the pieces together. To facilitate flawless installation, the bearings' rough dimensions have also been modelled. There haven't been much interference found between the gear tooth and the casings, but the casing's proportions have changed. The assembly is not interfering with the components, according to thorough checks of each component. It is determined from the assembly that the Gearbox takes up the least amount of room. The Assembly will be the subject of thorough examination. Figure 9 depicts the entire layout of gearbox.

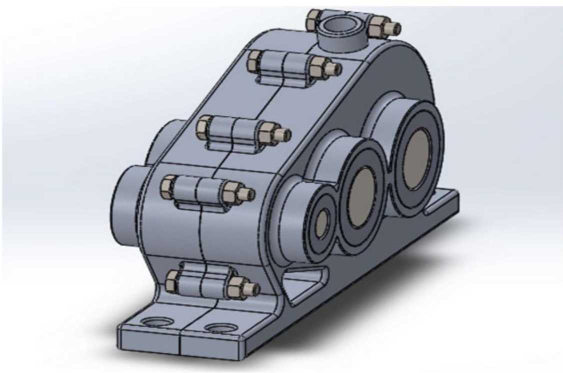

Fig. 9: 3D model of assembly of Gearbox

3.4 Design of Roll cage

The fundamental concept underwent several modifications before the design that provided the greatest feasible arrangement for attaching the components was chosen. The model of the finished CATIA V5 design is shown in figure 10.

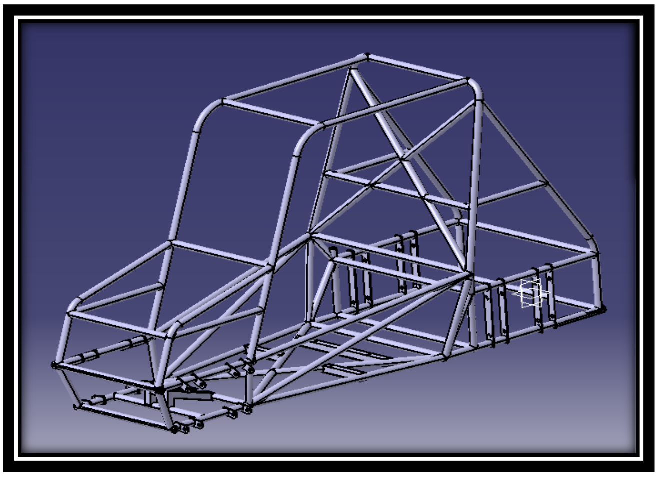

Fig. 10: CAD model of roll cage

3.5 Design of A-Arm

The A-arms were constructed using oval cross sections, which combine the advantages of both circular and square cross sections—strong in torsion and bending, respectively—in one structure. The material selected was mild steel, AISI 1020, with tensile and yield strengths of 394.7 MPa and 294.8 MPa, respectively. The design for A-arm is shown in figure 11. suspension geometry simulation done on Lotus suspension analysis gave us the value of spring force acting on the lower mount of the spring. This force was equally divided and applied on the two holes on the spring mount of the A-Arms. The inner part of the holes of the chassis mount of the A-Arms was constrained.

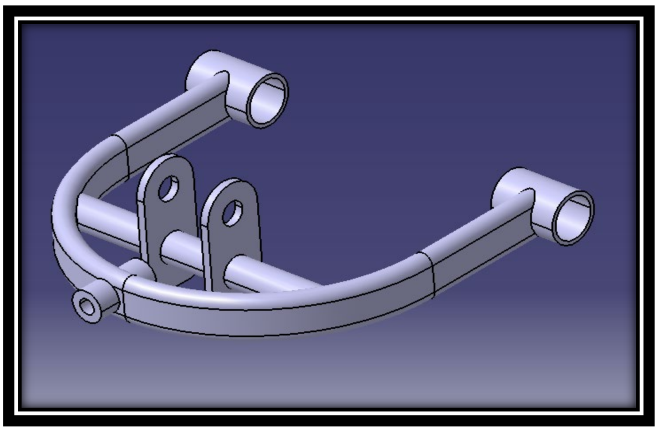

Fig. 11: CAD model of A-Arm

In order to join the wheel to the other components of the automobile and place the brake disc, the front hub was created. According on the information gleaned from the suspension geometry, the hub's dimensions were set. The hub's perforations were intended to match the brake disc's pitch circle diameter on one of the hub's flanges. The opposite flange, however, was made to match the wheels' utilized pitch circle diameter in order to ensure that the previously determined criteria, such as wheel track.

3.6 Design of Front Hub/Rear Hub

The front hub was meant to function as a mount for the brake disc as well as to connect the wheel to the rest of the car's structure as shown in figure 12. The rear hub was designed so as to serve as a mount for the brake disc, accommodate the drive shaft to transmit driving torque to the wheels and also attach the wheel to the other aggregates of the car. The dimensions of the hub were determined using data from the suspension geometry.

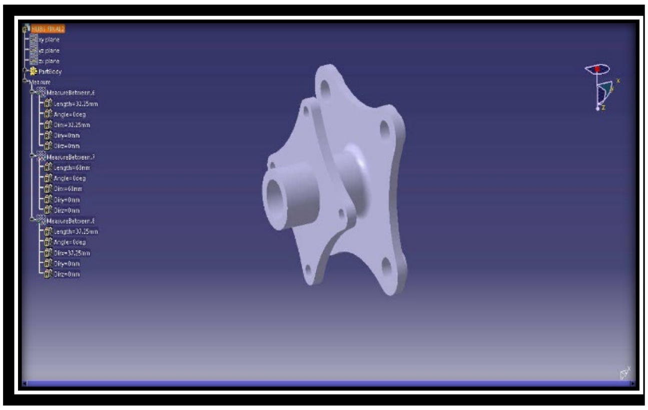

Fig. 12: CAD model of front hub

3.7 Design of Front Upright

As seen in the illustration of figure 13, the front upright was a dead axle type. The front upright was built to accommodate the needed suspension geometry while also serving as a mounting point for the brake calliper and steering arm.

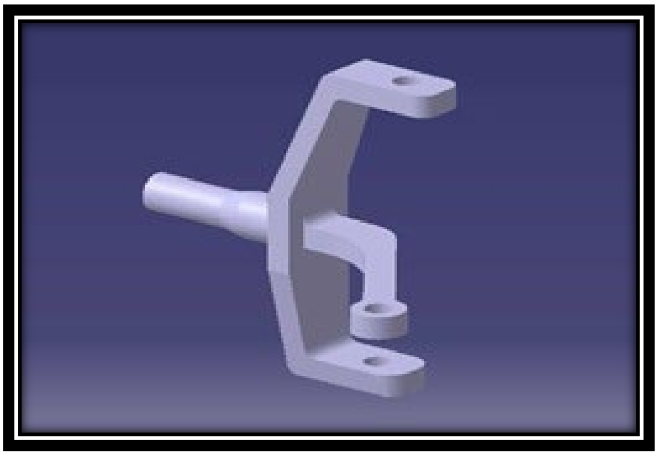

Fig. 13: CAD model of front Upright

3.8 Design of Rear Upright

The rear upright was designed to serve as a mount for the brake calliper and the control arm, which limits the toe angle values of the wheel during bumps. In addition, the design was created to accept the driving shaft without difficulty as shown in figure 14.

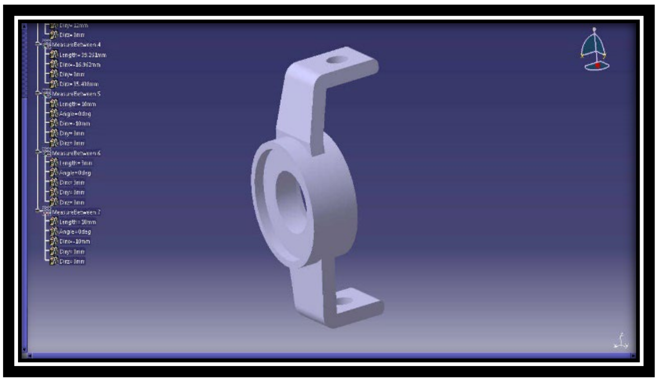

Fig. 14: CAD model of front Upright

3.9 Design of Brakes

Maximum braking performance is obtained without endangering the driver's life and while assuring synchronous locking of all four wheels. The primary types of brakes investigated were disc brakes and drum brakes.

At maximum deceleration of 1.1 g, weight transfer of 115.8 kg was estimated from following formula.

$$WT = \frac{W * y * d}{b * g}$$

Where, W= 320 kg (Overall weight of the vehicle)
y = 0.508 m (CG height)
d = 1.1 g (Maximum Deceleration)
b = 1.524 m (Wheel Base)

4. FEA Analysis Results

4.1 Analysis of Gears

High torque is applied to the internal gears during operation. The gear is susceptible to a twisting moment from the centre of the axis as a result of the high torque generated. There is very little resistance the gear provides against the torque since its centre is bonded to the shaft. The moment of inertia of the Gear, however, could temporarily withstand the torque due to the CVT's rapid torque fluctuation (milliseconds). Even if the shaft is mounted on low friction Roller bearings, it is necessary to do a torque analysis on the gears under the assumption that the shaft is fixed firmly. Different Gears Support Differing Torques and each gear have its own specific loading conditions.

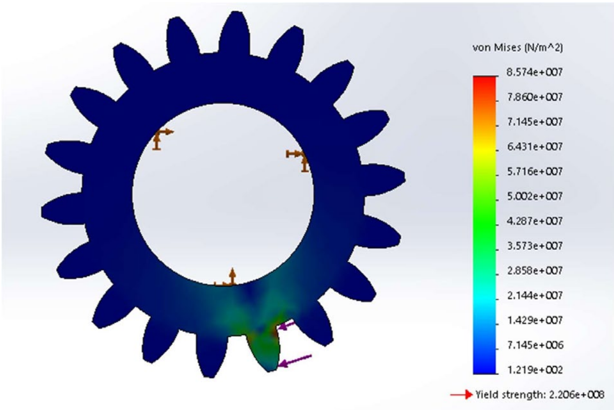

Fig. 15: Analysis of the Static Structure of Gear 1

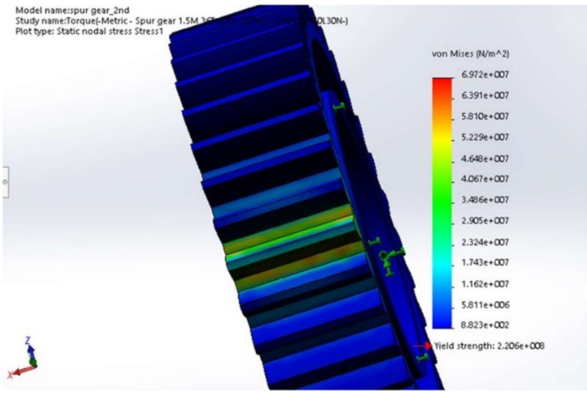

Fig. 16: Analysis of the Static Structure of Gear 2

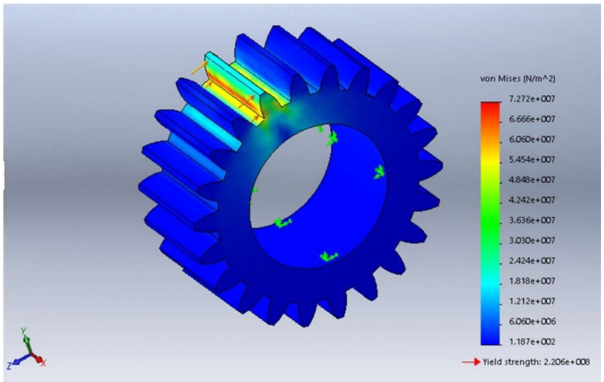

Fig. 17: Analysis of the Static Structure of Gear 3

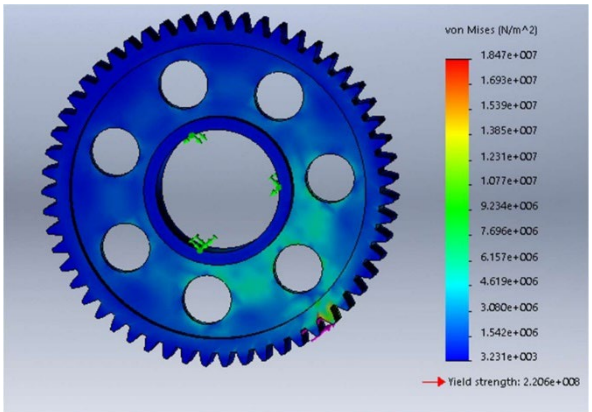

Fig. 18: Analysis of the Static Structure of Gear 4

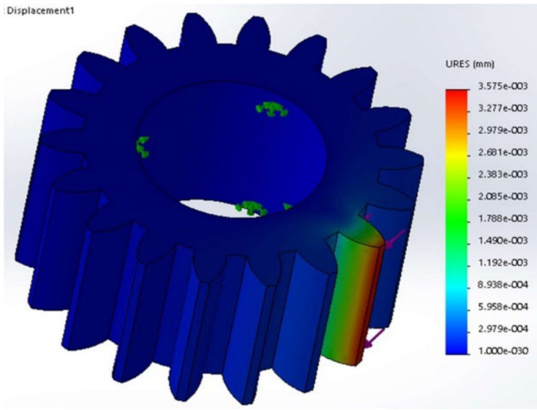

Fig. 19: Gear 1 - Displacement Analysis

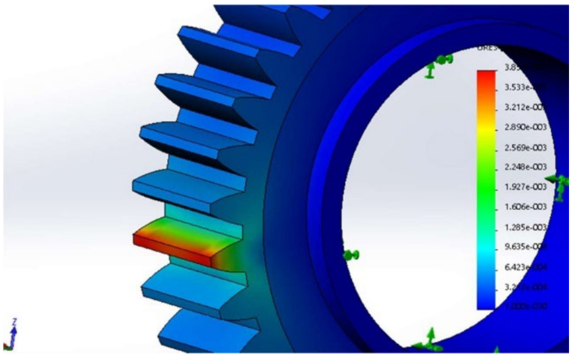

Fig. 20: Gear 2 - Displacement Analysis

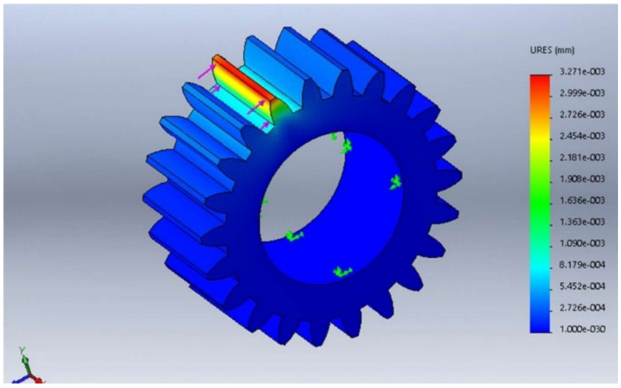

Fig. 21: Gear 3 - Displacement Analysis

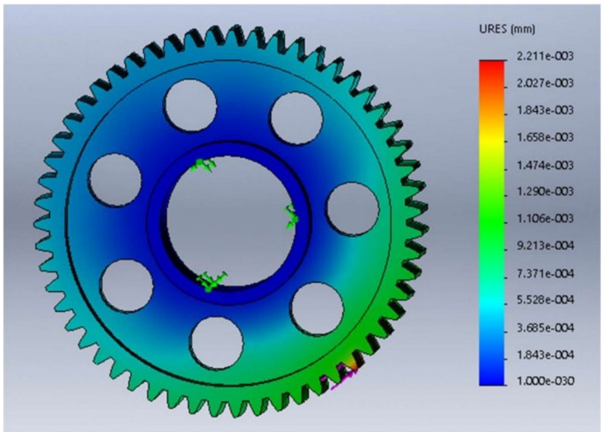

Fig. 22: Gear 4 - Displacement Analysis

Figure 15, Figure 16, Figure 17, Figure 18 highlights Static Structural Analysis on Gear 1, Gear 2, Gear 3, and Gear 4 respectively. Further, the displacement analysis of Gear 1, Gear2, Gear 3, and Gear 4 is shown in Figure 19, Figure 20, Figure 21, and Figure 22 respectively.

4.2 Vibration and Loading Effect on Gear Assembly

The engine vibrates at a frequency of about 50 Hz. The CVT and the input shaft of the gearbox both get vibrations from the engine. Practically speaking, transmission via CVT will result in severe loss. It is expected for safety reasons that the CVT can transfer all of the vibrations generated by the engine. The loading situation is further increased by the weight of the internal components and the gear grease. In order to prevent eccentricity or misalignment from occurring, the analysis aims to ensure that the casing completely absorbs all vibrations without disturbing the shafts and bearings. Aluminum alloy 7071-T6 with a 121MPa endurance limit serves as the casing's material.

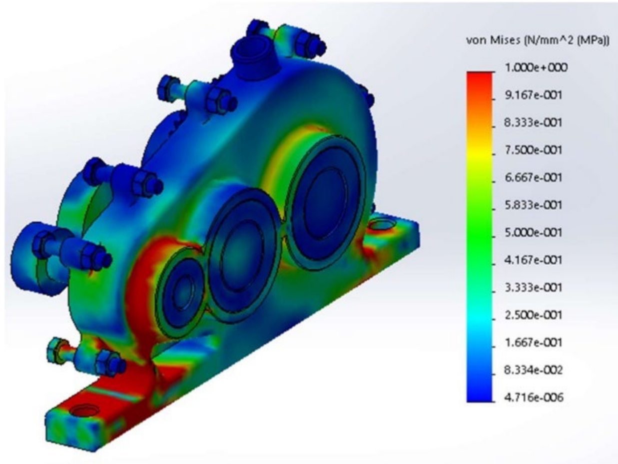

Fig. 23: Vibration Analysis on Assembly

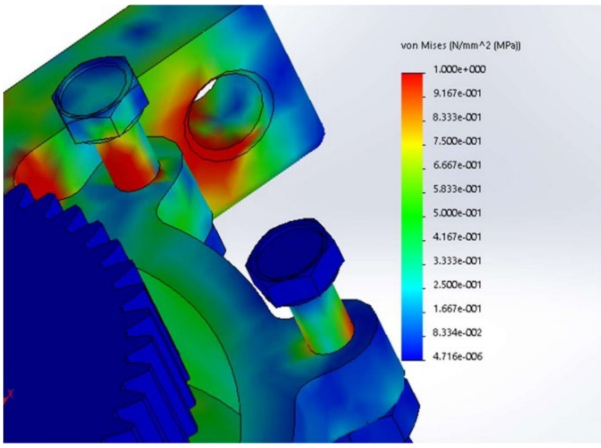

Fig. 24: Fasteners affected by Vibrations

Vibration Analysis on Assembly is shown in figure 23. Also, Fasteners are subjected to some vibration therefore; its analysis is mentioned in figure 24. Further, it is noted that shafts and bearing are majorly not affected by vibrations as shown in figure 24.

4.3 Analysis of Roll Cage

The impact on roll cage is important to analyze therefore, Figure 25, Figure 26, Figure 27 shows the analysis of roll cage from different perspective.

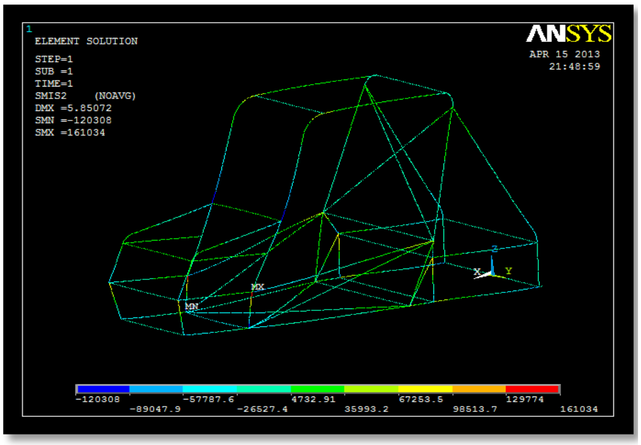

Fig. 25: Front Impact on roll cage

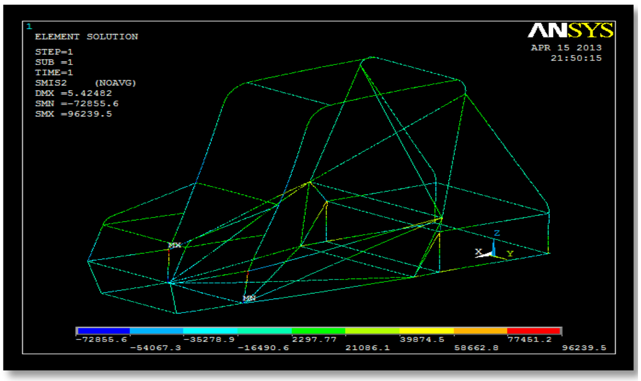

Fig. 26: Rear Impact on roll cage

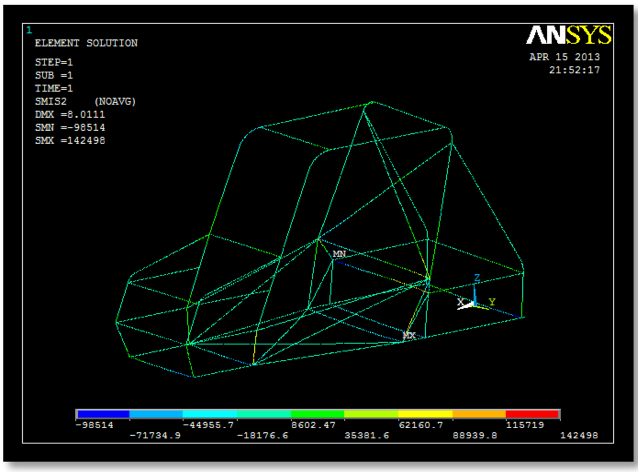

Fig. 27: Side Impact on roll cage

4.4 Analysis of A-Arm

The analysis of A-arm is shown in figure 28.The hole in the A-arm where the ball joint is connected was applied with a vertical force of magnitude stated below:

$$F = Vehicle\ Weight * \frac{5g}{2}$$

Hence,

F= 320*5*9.81/2 = 7.848 kN

5g is the standard acceleration used while calculating various forces.

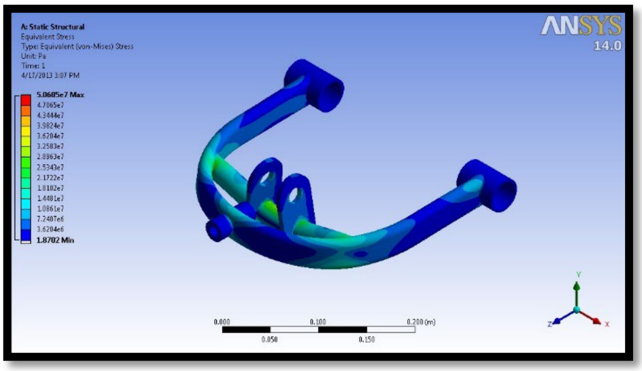

Fig. 28: Analysis of A-Arm

4.5 Analysis of Front hub

The conditions for analysis were as follows: The slots in the hub where the bearings were fit were constrained assuming a situation that the springs and uprights are perfectly rigid bodies with infinite stiffness. Vertical force acting on each wheel was calculated considering a situation where the entire car weight acts on a single wheel after a rough jump followed by a heavy landing. This vertical force would get transmitted to the hub through the wheel where the wheels are bolted to the hub. So the four holes were loaded with vertical force (F) of magnitude stated below:

$$F = Vehichle\ Weight * \frac{5g}{4}$$

Hence,

F= 320*5*9.81/4 = 3.924kN on each hole.

5g is the standard acceleration used while calculating various forces.

Also considering a situation where sudden brakes are applied, braking torque was applied on the four holes where the brake discs are mounted. The analysis of hub is shown in figure 29.

4.6 Analysis of Front Upright

The holes in the upright where the A-Arms are connected to the upright were constrained assuming a situation that the springs are rigid bodies with infinite stiffness as shown in figure 30.

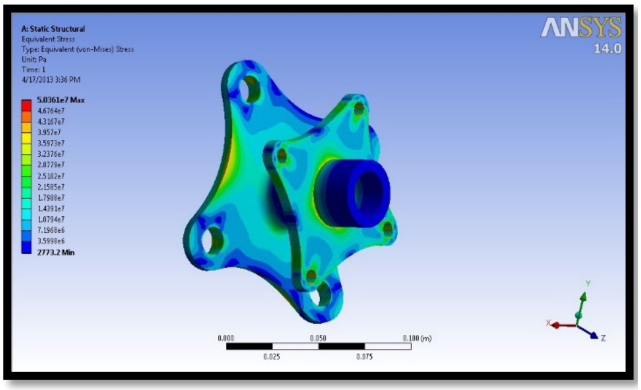

Fig. 29: Analysis of hub

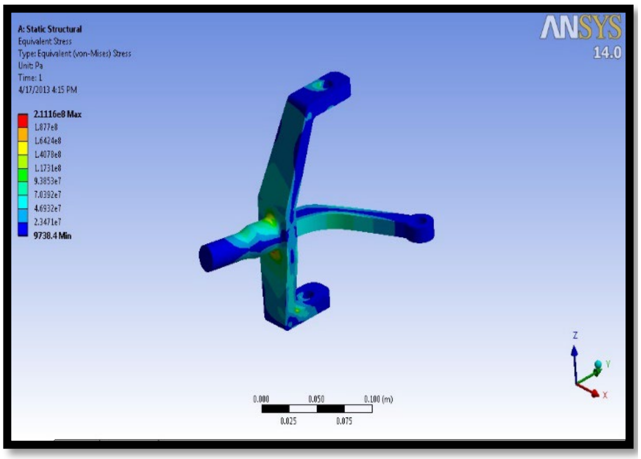

Fig. 30: Analysis of Front Upright

Vertical force acting on each wheel was calculated considering a situation where the entire car weight acts on a single wheel after a rough jump followed by a heavy landing. This vertical force would get transmitted to the upright through the wheel and then the hubs to the axle of the upright where the bearings are mounted. So the lower half portion of the stub axle where the bearings were mounted were loaded with vertical force (F) of magnitude stated below:

$$F = Vehicle\ Weight * 5g$$

Hence,
F= 320*5*9.81 = 15.696kN

5g is the standard acceleration used while calculating various forces.

4.7 Analysis of Rear Upright

The holes in the upright where the A-Arms are connected to the upright were constrained assuming a situation that the springs are rigid bodies with infinite stiffness. Vertical force acting on each wheel was calculated considering a situation where the entire car weight acts on a single wheel after a rough jump followed by a heavy landing. This vertical force would get transmitted to the upright through the wheel and then the hubs to the area on the upright where the bearings are mounted. So the upper half portion of the area where the bearings were mounted were loaded with vertical force (F) of magnitude stated below:

$$F = Vehicle\ Weight * 5g$$

Hence,
F= 320*5*9.81 = 15.696 kN

5g is the standard acceleration used while calculating various forces.

The analysis of rear upright is shown in figure 31.

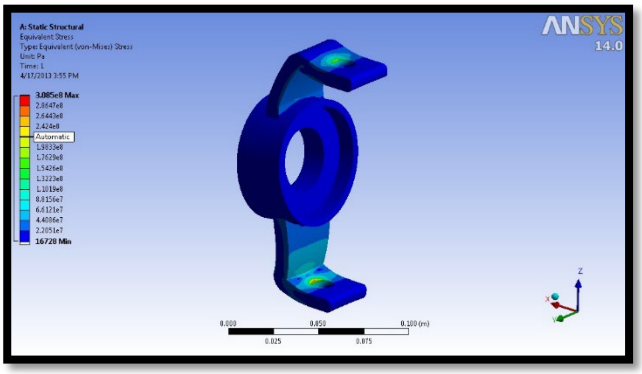

Fig. 31: Analysis of Rear Upright

5. Discussions

The Society of Automotive Engineers, India is the organization that sponsors the BAJA intercollegiate competition. Its objective is to construct an All-Terrain Vehicle (ATV) within the boundaries established by the organizers[15]. A low-cost ATV's design and development demand specific resource management and use. One particular difficulty is of particular importance when taking into account local manufacturing capabilities, particularly for prototyping. The SAE BAJA competition, which began in 1976 to inspire engineering students to form teams to develop and produce lightweight ATVs to compete in a real field setting, is regarded as a significant milestone in the design and low-cost production of vehicles[16]. ATV production took place after the design and calculations were carried out with better results. Gear lubrication is always required to prevent gear teeth from wearing out or getting damaged. Heat is generated within the gearbox as a result of frequent meshing and contact between gears, lowering gearbox efficiency. Lubrication reduces mechanical losses by using the appropriate oil for the conditions. Too much oil in the gearbox might result in churning losses. To avoid this, a CFD study was undertaken in order to maintain the least quantity of oil necessary in the gearbox[17,18]. There are several factors that influence top speed. Rolling resistance, aerodynamic drag, and drive train losses are examples of these[8,9]. CFD methods have been validated[19] for estimating gear splash loss, gear windage, and gear pair splash loss[20]. Some previous studies explain how to compare the outcomes of numerical simulations and experimental research utilizing the finite element method, the discrete element method[21]. The results obtained in the current research are in line with the previous findings[22,23]. Condition monitoring of the transmission assembly was performed using vibration signals collected from an all-terrain vehicle (ATV) transmission. From the results of finite element analysis, they identified the defective parts of the gear[24–26].

Key criteria such as tractive effort, acceleration behavior, climbing ability and top speed of the vehicle were evaluated and the reduction ratio was calculated accordingly. This reduction ratio was used to construct a two-stage reducer and its parts. Designers spoke about key factors that affect overall design, such centre distance and diametral pitch. The finite element analysis is employed to validate the design which is nearly matching with the current research[27]. The gearbox has gone through intensive design, analysis and calculation. Since the first stage is 2.64 and the second stage is 2.73, the final gear ratio is 7.22. The entire gearbox is made of AISI 4340 steel, except for the gearbox housing. The gear housing is made of AI6061-T6 material by previous researchers. All gears, gearboxes and cases were researched and presented. The Jaabaz India team's TJ19 vehicle uses the transmission at the BAJA SAE California competition. With proper maintenance, all components have complete gear ratios, minimum tooth count, bearing force and analysis that can withstand the harsh conditions of an ATV for about two years[11]. In order for the transmission and braking system of the All-terrain Vehicle to provide the All-terrain Vehicle with the maximum amount of acceleration and deceleration, some study has been carried out primarily concentrating on the longitudinal vehicle dynamics portion[12].

Multibody simulation tools are often used to evaluate vehicle performance prior to vehicle manufacture[28–30]. The all terrain vehicle suspension was simulated and analyzed by Solidworks16 in past studies[13]. Thereby, it was intended to perform the analysis of present gearbox by using Finite Element Analysis[31,32]. Further, few approach carried out for modelling, designing, and analyzing the E-BAJA vehicle's unique coil springs and rear suspension system[31]. Thus, it was analyzed that the gear box design is safe and can be adopted for real time application of ATVs[33].

5.1 Stress Distribution Variations

The outcomes of Finite Element Analysis (FEA) might exhibit fluctuations in stress patterns at distinct regions within the ATV component. These fluctuations may serve as indicators of regions characterized by high stress concentration, potential points of failure, or areas necessitating additional reinforcement.

Fluctuations in stress responses under diverse loading scenarios: FEA results can demonstrate the evolution of stress levels under various loading conditions, including static loads, dynamic loads, or thermal loads. These variations in stress patterns are instrumental in identifying critical loading scenarios that warrant special consideration during the component design process.

5.2 Deformation Characteristics

Fluctuations in the deformation patterns observed across the component provide insights into its response to applied loads. These fluctuations can pinpoint areas susceptible to excessive deformation or deflection, offering guidance for design modifications.

Vibrational modes of the component may exhibit variability, offering insights into how the component responds to dynamic forces. Recognizing and understanding these modes are pivotal for optimizing structural integrity and averting resonance-related issues.

6. Conclusions

All-terrain vehicle gearboxes take up more space, heavy, and have a finite lifespan depending on how they are used. Continuous use of these Gearboxes generates heat that might compromise the structural integrity. A CVT that may change transmission ratios is intended to be paired with the reduction gearbox. As the engine RPM rises, the CVT's transmission ratio falls. It may be concluded that all the components are not prone to failure within the specified operating limits based on the analytical calculations and Finite Element Analysis. The Gearbox of ATV has a longer lifespan than traditional manual gearboxes and is lightweight and small.

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