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ANSYS Workbench for Steering Bracket Design and Analysis

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ABSTRACT

The steering knuckle is where the front wheel's suspension, hub, steering system, and braking system all attach to the vehicle's chassis. Using the steering mechanism, the Steering Knuckle directs movement in the desired directions. Numerous stresses and strains are applied to it. A lighter steering knuckle is essential for vehicles because it increases power and decreases vibration by reducing inertia. We examine the steering knuckle in detail and report on its structural strength, thermal efficiency, fatigue resistance, and modal features. An FEA study of a steering bracket must include the usage of Structural Steel, C35 Alloy Steel, and 30C8 Alloy Steel. Mechanical testing under load may be used to measure deformation, stress, strain, safety factor, temperature, modal deformations, and other material properties. Computer aided engineering (CAE) is used to create the steering knuckle. After a Catia model of the steering knuckle is created taking into account constraints and loads, it is analysed in Ansys Workbench.

Keywords:

Catia V5 Analysis of a Steering Bracket with C35 and 30C8 Alloy Steels.

INTRODUCTION

The automotive industry created four-wheel steering to improve vehicle manoeuvrability and turn radius. The effectiveness of conventional front-wheel-drive vehicles' steering is diminished since their rear wheels do not pivot in the same way. Four-wheel steering improves fuel economy since the vehicle's rear wheels are coordinated with the front. The rear wheels may be steered in a different direction from the front wheels depending on how the vehicle is being driven. Wheel movement is more noticeable at low speeds, allowing the rear to be guided in the opposite direction of the front. Parking, low-speed cornering, and high-speed lane changes all benefit from a smaller turning radius achieved by modest steering adjustments made while traveling at high speed. Low-speed cornering and city driving both provide challenges for vehicles with a larger

wheelbase and track width due to space constraints. Since these issues are more common in vehicles with a wider track and longer wheelbase, the concept of four-wheel steering can be implemented to address them. In this project, four-wheel steering is added to the already existing vehicle to decrease the turning radius without increasing the vehicle's overall size, making it more manoeuvrable in tight spaces. The phrase "steering" is used to describe the system of levers, wheels, cables, and other mechanisms that directs a ship, boat, or vehicle in the intended direction. One notable example is rail transportation, which uses a steering column (perhaps equipped with universal joints) in conjunction with rail tracks and railroad switches to allow for some lateral movement. A hand-operated steering wheel in front of the driver is the most common method of guiding the front wheels.

Wheeled Vehicle Steering

Basic geometry

The primary function of steering is to guide the vehicle's wheels. Common mechanisms for doing this include links, rods, pivots, and gears. Caster angle, in which each wheel has its pivot point in front of it, is a key notion because it causes the wheels to naturally cant in the direction of motion. When making a turn, the inner wheel is actually traveling a path of smaller radius than the outer wheel; thus, the degree of toe suitable for driving in a straight line is not suitable for turns, and so the steering linkages connecting the steering box and the wheels usually conform to a variation of Ackermann steering geometry to account for this. Camber angle, or the angle of the wheels relative to the vertical plane, also affects steering dynamics. Rack and pinion steering is used in many contemporary automobiles; the driver spins the pinion gear, which in turn rotates the rack, a linear gear that meshes with the pinion to transform the driver's circular input into a linear output along the transverse axis of the vehicle (side to side motion). This action transmits steering torque to the steered wheels' swivel pin ball joints through tie rods and a small lever arm known as the steering arm. Rack and pinion steering systems provide the benefits of high feedback and a natural "feel" while turning. The fact that it can't be tightened or loosened means that the only solution to wear and lash is to get a new one.

Description on Problem Statement

Steering technology for automobiles has been a hot topic in engineering for the last decade due to the fact that it is amenable to continual improvement, which in turn leads to greater quality with fewer troubleshooting and production problems. Research and development (R&D) divisions allocate resources in this way to address the problem. To comprehend the functioning of a steering system, theoretical analysis is helpful. An important part of any steering system is the steering bracket, which helps to evenly disperse the workload. According to the deformation hypothesis, the whole dimension of the steering bracket shifts when the flow takes control. So, deformation is the most useful theory for evaluating issues related to the steering system. Steering brackets in vehicles are among the most

practical forms. To accommodate the changes in the design, new parts had to be fabricated. As important as these tweaks to the steering method are, however, it was also important that the manufacturing process be as consistent as possible. Because of this, there have been recent advancements in the field of Steering System design. In this presentation, we use Finite Element ways (FEM) and theoretical techniques to provide ways for analysing a steering system.

Methodologies Used

Summary of capabilities

New features are being added regularly, as is the case with all software. The following is an overview of the product's features and capabilities, not a detailed description of each function. Catia Elements, along with comparable products on the market, is a kind of computer-aided design (CAID), computer-aided manufacturing (CAM), and computer-aided engineering (CAE). 12 Catia Elements is a sophisticated rule-based design system that incorporates parametric, feature-based modelling architecture into a unified database concept. Engineering design, analysis, and optimization are the three primary categories into which the product's features fall. This information is subsequently recorded in either a normal 2D production drawing or a 3D ASME drawing.

Engineering Design

Several options are available in Catia Elements for creating a comprehensive digital model of the product being designed. Other integrated design disciplines, such as industrial and standard work and comprehensive wiring specifications, may have their geometry generated using the same tools as general geometry. There are various tools available to facilitate teamwork throughout the development process. The downstream process of developing the product might benefit from a variety of concept design tools that generate first Industrial Design ideas. Industrial design drawings, point cloud data for reverse engineering, and full-featured freeform surface tools are just a few examples.

Finite Element Analysis

Ansys Elements is a suite of analytic tools designed to speed up the product development process. These tools encompass thermal, static, dynamic, and fatigue FEA analysis. Methods like this include things like optimizing for human factors, manufacturing tolerances, mild flow, and design. The best outcomes may be achieved by combining geometric optimization of the design with finite element analysis.

LITERATURE REVIEW

1. Dinesh Babu S, Farug H, Tanmay Mukherjee (2017) – Design & Analysis of Steering System for a Formula Student Car

The Formula Student India team has been toiling away at its take on the iconic single-seater race car. The goal is to design a steering system that is not only user-friendly but can also automatically adjust to changing track conditions. After a mathematical model is established, it is validated geometrically, and then the entire steering system is modelled in Solid Works and CATIA V5. Since stress is generated in any mechanical system, ANSYS Workbench is used to perform a static analysis to investigate the static stress distribution. Altair Hyperworks' Multi-Body Dynamics (MBD) analysis ensures the steering system's dynamic response. The following inferences may be made from information obtained from this helm system: When compared to other angles, camber's change over time is negligible. Second, the stress yielded is much below the limit of the yielding point of Al 7075 T6, making the design risk-free at a significantly lower weight than steel. Third, since the steering angles are consistent, the steering effort is also consistent.

2. Mobin Majeed, Greg Wheatley (2020) – Steering System Design of the Second-Generation Formula SAE

The purpose of this research is to provide insight into the design of steering systems for formula racing vehicles. Primary design was done in Solid Works, while analysis and simulation were performed using finite elements. Calculated wheel loads are an integral part of Formula One car analysis. The at-arms may proceed unimpeded when the steering rack was relocated. The yield strength of the bolts used to attach the tie rod to the clevis and the clevis to the mounting bracket has been severely exceeded. ANSYS performed stress and fatigue testing on the rack's final clevis and determined it to be without flaw. After looking at the potential failure spots of the rack arm, we found that it is resilient enough to withstand a lot of different kinds of stress throughout the duration of its useful life. After disassembling the steering system, individual components such as the steering

column assembly, the steering rack assembly, and the tie rod assemblies were each designed in Solid Works. SKF SAKAC bearings are what we utilize. While the rack arms and upright assembly are fixed to one another with 10 M rod ends, the wheel assembly has full freedom of movement in the vertical plane. There are 12 pieces total, including screws in sizes M8 and M10 as well as the washers and nuts that go with them. The universal connection that joins the two steering columns was machined using Australian-standard splines. Two splined columns must be machined for the steering column.

3. Dr. S. Neel Krishnan, Kowshik T, Krishnakumar G, Bharathi Mohan M P (2017) – Analysis and Improvement of the Steering Characteristics of an ATV

The primary goal is to analyse the steering behaviour of the ATV to enhance the vehicle's manoeuvrability. When navigating tight turns with our BAJA buggy from the previous year, we frequently lost control and went off the track because of excessive oversteer. We are developing a system with a lower steering ratio of 3:1 to accomplish this. This makes driving the automobile simpler for the driver. The primary goal of this project is to address the problems that have afflicted a BAJA buggy used in engineering contests. The addition of a steering gear box and a steering upright enhances the functionality of the steering system. After analysing the planned components, the simulation procedure begins. The BAJA buggy's performance may be improved with the use of analysis and simulation findings.

4. Sanjay Yadav, Ravi Kumar Mishra, Varish Ansari, Shyam Bihari Lal (2016) – Design and Analysis of Steering Knuckle Component

The most crucial portion of any vehicle is the steering knuckle, which links the front wheel to the suspension, wheel hub, and 17-inch steering system/brake assembly. With the use of the steering mechanism, the Steering Knuckle directs movement in the desired directions. It's subjected to a wide range of conditions and loads. Since the lighter steering knuckle results in greater power and less vibration due to reduced inertia, it is one of the primary demands in the automotive industry that vehicles meet. Static analysis of the steering knuckle was performed for this paper.

PROJECT METHODOLOGY

Principle of Steering

The steering system has to be responsive enough for accurate control of the vehicle's movement, light enough for simple parking, resilient enough to recover when the driver releases the wheel during a

turn, and shock-absorbing enough to keep the ride comfortable. The steering system enables accurate movement control, simple mobility, rapid recovery from turns, and little stress transmission to the road surface.

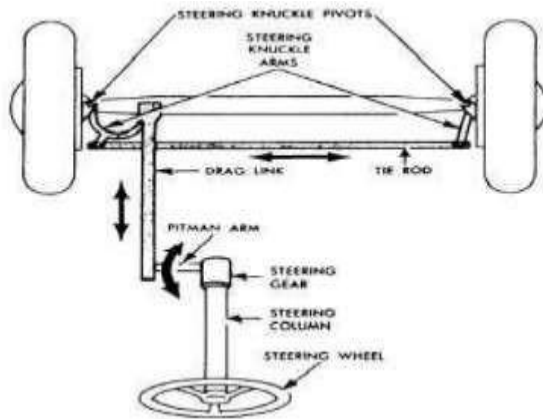


Figure 1 Steering diagram

The box in the middle of the dashboard receives directional directions from the steering wheel through the column. The wheel's revolution is translated into forward or backward motion via the steering box. The driver might benefit mechanically as well. Linear motion is transmitted from the steering box to the front wheels' steering arms through tie-rods. Ball joints on the tie rods allow the suspension and steering to move. Isolating the steering from the suspension movement is the purpose of the ball joints in the steering arms.

MATERIAL PROPERTIES USING FOR STEERING BRACKET

Materials Properties Used 1- Structural Steel

Method - 1

Composition

Carbon	≤ 0.08
Manganese	≤ 2
Silicon	≤ 1
Sulfur	≤ 0.03
Phosphorous	≤ 0.045
Chromium	18 – 20
Iron	66.345 – 74
Nickel	8 – 10.5

Table 1 Mechanical Properties Structural Steel

Mechanical Properties

Density (kg/m^3)	7850
Tensile Strength (MPa)	505
Yield Strength (MPa)	215
Possions Ratio	0.3
Modulus of Elasticity (GPa)	210

Method 2- C35 Alloy Steel

Composition

Carbon	0.39
Manganese	0.80
Silicon	0.35
Sulfur	0.035
Phosphorous	0.030
Chromium	0.30
Nickel	0.30

Table 2 Mechanical Properties C35 Alloy Steel

Mechanical Properties

Density (kg/m^3)	7800
Shear Modulus (GPa)	80
Yield Strength (MPa)	345
Tensile Strength (MPa)	520-690
Specific heat ($\text{J/kg}^\circ\text{K}$)	460 - 480
Possions Ratio	0.3
Modulus of Elasticity (GPa)	210

Method -3- 30C8 Alloy Steel

Composition

Carbon	0.030 - 1.25
Manganese	0.20 - 16
Iron	80 - 98
Phosphorous	≤ 0.050
Silicon	0.00 - 0.50
Sulfur	≤ 0.050

Table 1 Mechanical Properties 30C8 Alloy Steel

Mechanical Properties

Density (kg/m^3)	7900
Shear Modulus (GPa)	80
Yield Strength (MPa)	350
Tensile Strength (MPa)	420
Poisson's Ratio	0.25
Modulus of Elasticity (GPa)	200

Table 4: Boundary Conditions

S.No	Description	Value
1	Element Type	Tetrahedron Element
2	Static Loads	800 N
3	Temperature	120°C
4	Heat Transfer Coefficient	50 W/m ² °C
5	All Body Mounts constrained	Tx, Ty, and Tz

DESIGN METHODOLOGY OF STEERING BRACKET

Introduction to CATIA

The French company Dassault Systems developed a cross-platform CAD/CAM/CAE suite called 3DEXPERIENCE. We refer to it as CA3D. Dassault Systems' CLM software suite is based on the 3D modelling and simulation platform CATIA. Competitors to CATIA in the high-end CAD/CAM/CAE market include Cero Elements/Pro and NX (Unigraphics). Dassault

Systems' CATIA V5 3D CAD program came out in 1999. This was a completely different design program from its predecessor, CATIA V4. With Windows 10, it's possible to install programs like Microsoft Office, graphic design software, and SAPR3 solutions with a single mouse click. The purpose of CATIA V5 is to digitally include the whole product development process, beginning with the first concept and ending with the manufactured good. This computer-aided design (CAE) training course will focus mostly on the workbench's mechanical parts.



Workstations may be set up in any configuration the user desires. There are three distinct approaches of installing software from Dassault Systems. The P1 system is used for training or when just the most fundamental capabilities are required. P2 is the ideal choice for process-oriented tasks. Besides the standard set of design features, it also includes analysis and production tools. The P3 level includes complex tasks like integrating third-party apps. In addition to its potential usage in the aerospace and military, automotive, and industrial equipment, high technology, shipbuilding, consumer products, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services sectors, CATIA has a wide range of potential applications. CATIA versions 4, 5, and 6 are the most popular, followed by Pro/ENGINEER, NX (previously Unigraphics), and Solid Works.

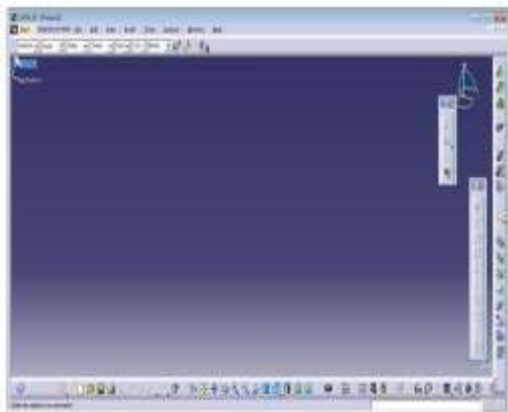


Figure 2 Home Page of CatiaV5

History

CATIA was developed in-house by French aircraft maker Avions Marcel Dassault in 1977 so that its Mirage fighter plane could be better designed. Since then, several industries have adopted CATIA, including the aviation, automotive, and maritime ones. Dassault rebranded the software from its original moniker, CATIA (Conception Assistée Tridimensionnelle Interactive; French for "Interactive Aided Three-dimensional Design"), after establishing a distribution company and signing a non-exclusive distribution agreement with IBM in 1981. After Boeing, CATIA's largest client at the time (1984), accepted version 3 of the program, CATIA was migrated from mainframes to UNIX in 1985. General Dynamics Electric Boat Corp. selected CATIA as their main 3D CAD tool in 1990 to use in the development of the Virginia class submarine for the United States Navy. Since 1978, IBM's worldwide distribution network has supplied Boeing's CADAM CAD system. In 1992, CATIA purchased CADAM from IBM, and in 1993, CATIA CADAM V4 was made available to the general public. As of 1996, ports were available for Hewlett-Packard HP-UX, Sun Microsystems SunOS, Silicon Graphics IRIX, and IBM AIX. CATIA V5, which was rewritten between 1998 and 2001, is compatible with UNIX, Windows NT, and Windows XP. Dassault released CATIA V6 to the general market in 2008. The servers may run either Linux or AIX, but only Windows PCs are supported. Dassault introduced Catia V6R2011x in November 2010 as the latest version of their PLM2.0 platform, and the company is still supporting and improving Catia V5.

ANALYSIS OF STEERING BRACKET

Analyses of the Steering Bracket are performed in Ansys. In order to finish the Steering Bracket, moments must be applied at certain spots along particular axes. The bottoms of the component's legs provide for great anchor locations.

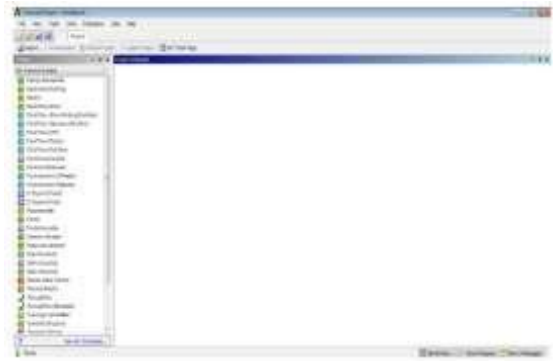


Figure 3 Import panel in Ansys

Meshing

As a representation of a geometric domain, a mesh may be either polygonal or polyhedral, and its production is referred to as "mesh generation." In common use, "grid generation" may mean a variety of different things. Visualization is widely used in fields such as finite element analysis and computational fluid dynamics. Common input model formats include CAD, NURBS, B-rep, and STL (file format), however more formats are feasible. Many fields, including mathematics, computer science, and engineering, have made important advances in this area. Finite element analysis necessitates the use of three-dimensional meshes in the form of tetrahedra, pyramids, prisms, or hexahedra. Any sort of polyhedral elements may be used in the finite volume method. Finite difference methods need the usage of multi-block structured meshes, often made up of arrays of hexahedra. Computer-aided engineering (CAE) relies on meshing to simulate real-world conditions. The mesh has a role in the convergence, speed, and accuracy of the solution. In addition, the time needed to receive results from a CAE tool might be significantly increased by the time spent constructing a mesh model. That's why high-tech, automated meshing technologies are necessary to get at the best possible answer. Whether you need a basic automated mesh or a meticulously crafted one, ANSYS is your best bet. Strong automation tools that key off physics parameters and employ sensible defaults make it simpler to mesh a new shape the first time around. In addition, users may immediately adapt to a parameter change, enabling preliminary design and the transfer from CAD to CAE. ANSYS's meshing tools let users to construct meshes of different complexity, from basic hex meshes to complicated Hybrid meshes with thousands of vertices, after the appropriate design has been identified.

DISCUSSION ON ANALYSIS RESULT

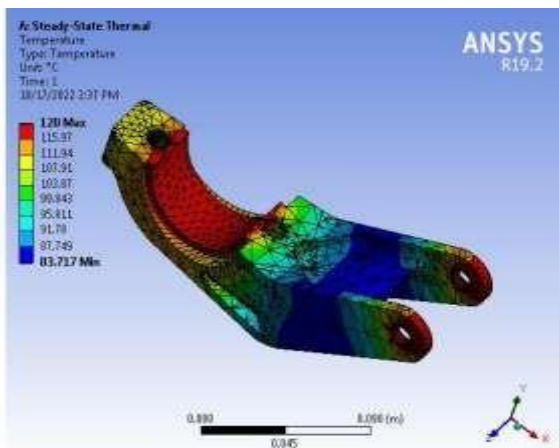


Fig: 4SB - Steel - Thermal – Temperature

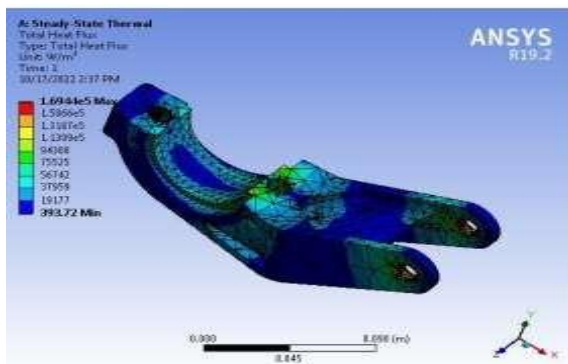


Fig:5SB - Steel - Thermal - Total Heat Flux

Table 5 Thermal Analysis Results of Structural Steel

Analysis Type	Results	Structural Steel
Thermal Analysis	Temperature (in °C)	83.717
	Total Heat Flux (in W/m²)	1.69E+05

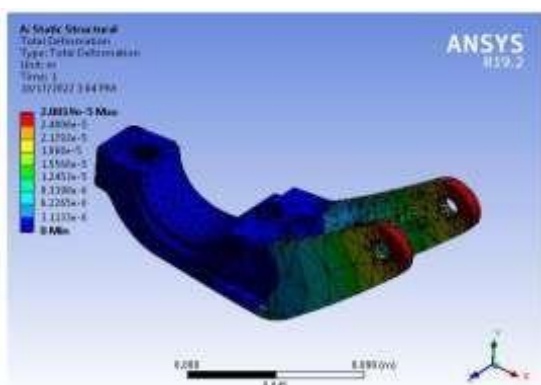


Fig: 6SB - Steel - Structural – Deformation

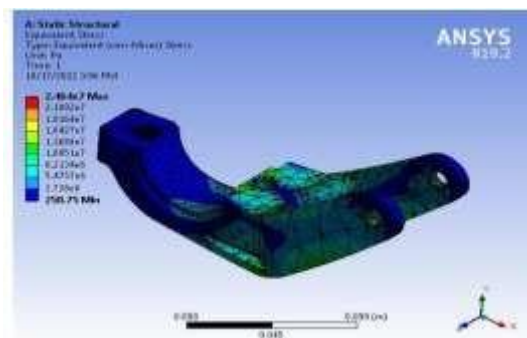


Fig: 7SB - Steel - Structural – Stress

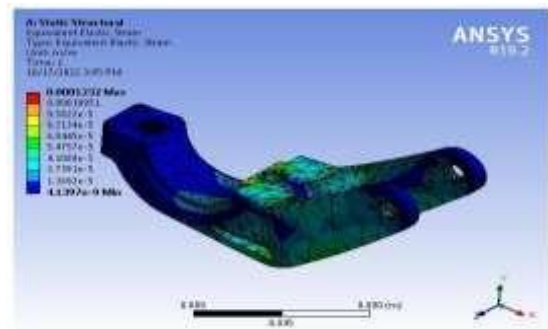


Fig: 8SB - Steel - Structural – Strain

Table 6 Structural Analysis Results of Structural Steel

Analysis Type	Results	Structural Steel
Structural Analysis	Deformation (in m)	2.80E-05
	Stress (in Pa)	2.46E+07
	Strain (in m/m)	0.0001232

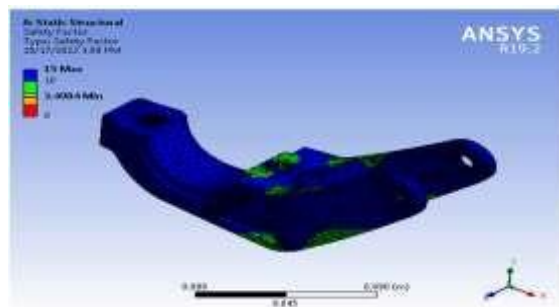


Fig: 9 SB - Steel - Fatigue - Safety Factor

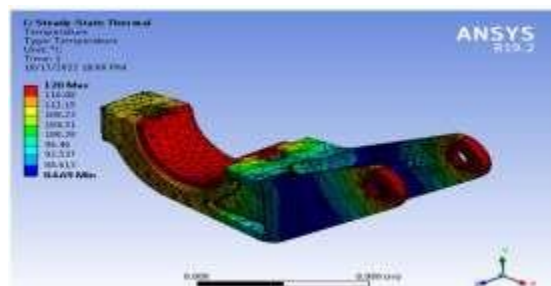


Fig: 10 SB - C35 - Thermal – Temperature

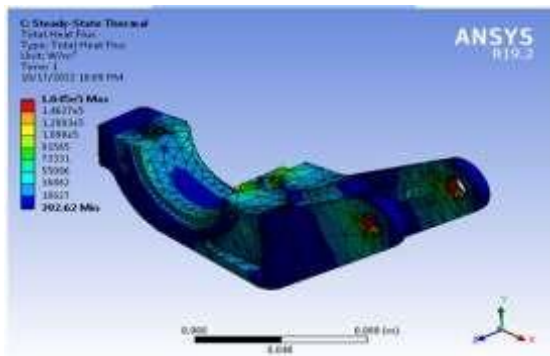


Fig:11 SB - C35 - Thermal - Total Heat Flux

Analysis Type	Results	C35 Alloy Steel
Thermal Analysis	Temperature (in °C)	84.69
	Total Heat Flux (in W/m²)	1.65E+05

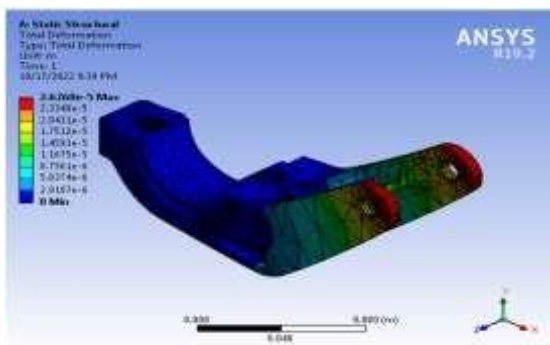


Fig: 12 SB - C35 - Structural – Deformation

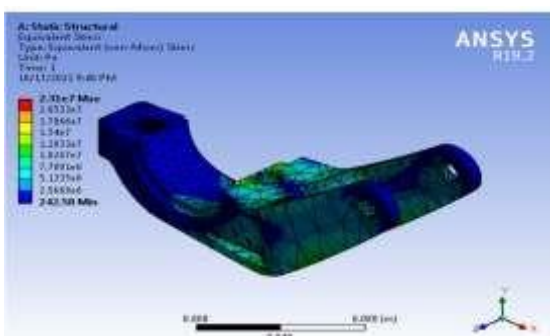


Fig: 13 SB - C35 - Structural – Stress

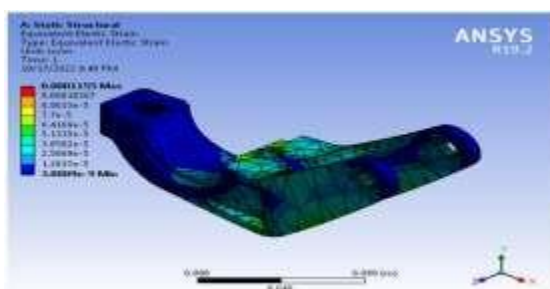


Fig: 14 SB - C35 - Structural – Strain

Analysis Type	Results	C35 Alloy Steel
Structural Analysis	Deformation (in m)	2.63E-05
	Stress (in Pa)	2.31E+07
	Strain (in m/m)	0.0001155

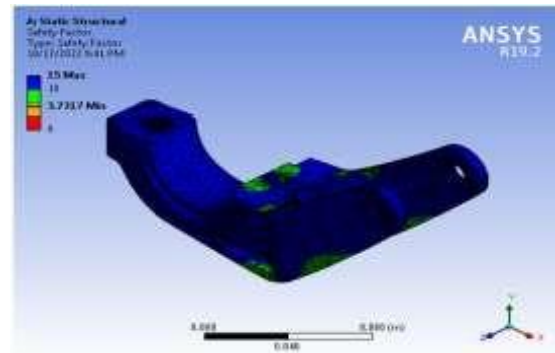


Fig: 15 SB - C35 - Fatigue - Safety Factor

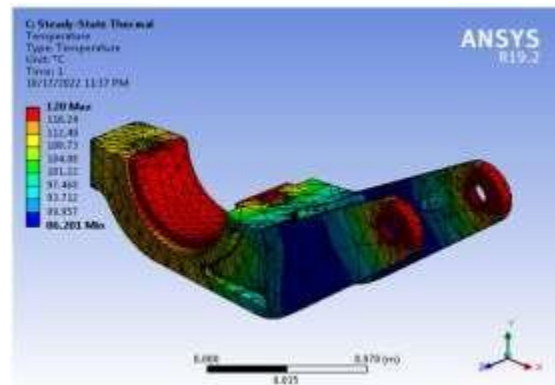


Fig: 16 SB - 30C8 - Thermal – Temperature

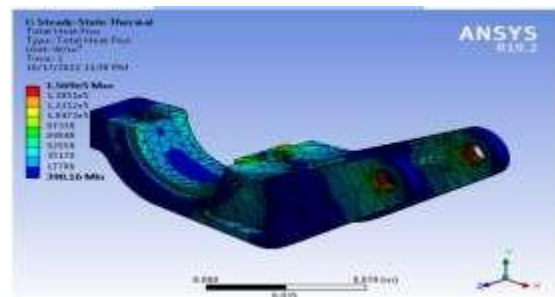


Fig: 17 SB - 30C8 - Thermal - Total Heat Flux

Analysis Type	Results	30C8 Alloy Steel
Thermal Analysis	Temperature (in °C)	86.201
	Total Heat Flux (in W/m²)	1.57E+05

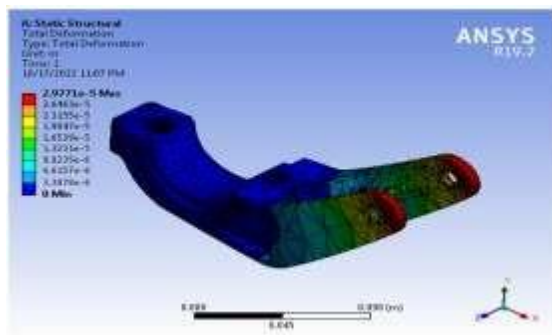


Fig: 18 SB - 30C8 - Structural – Deformation

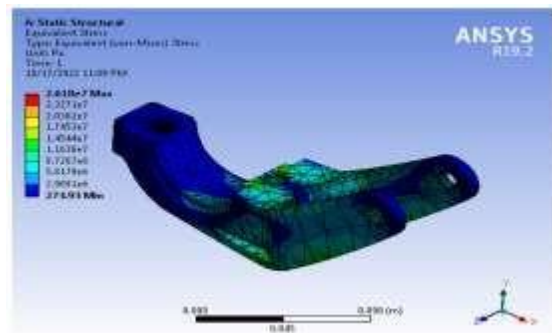


Fig: 19 SB - 30C8 - Structural – Stress

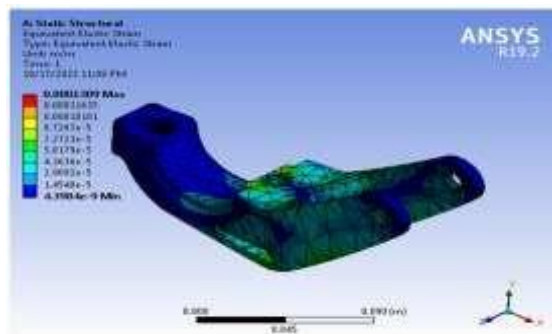


Fig: 20 SB - 30C8 - Structural – Strain

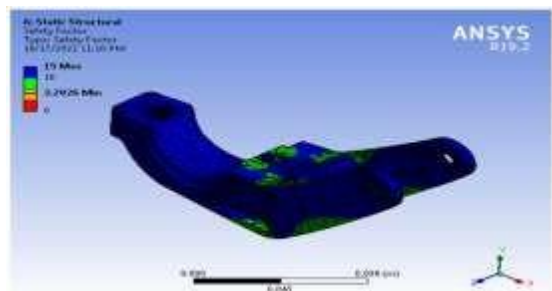
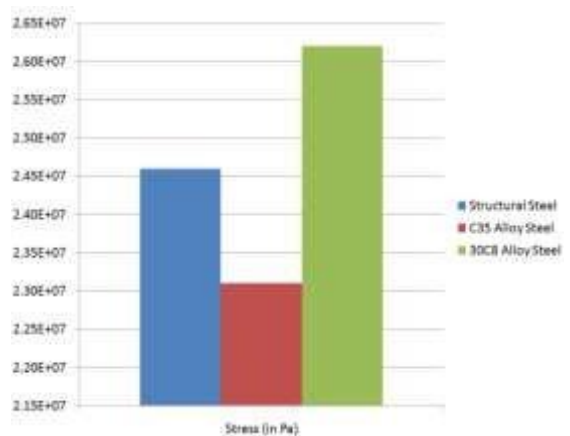
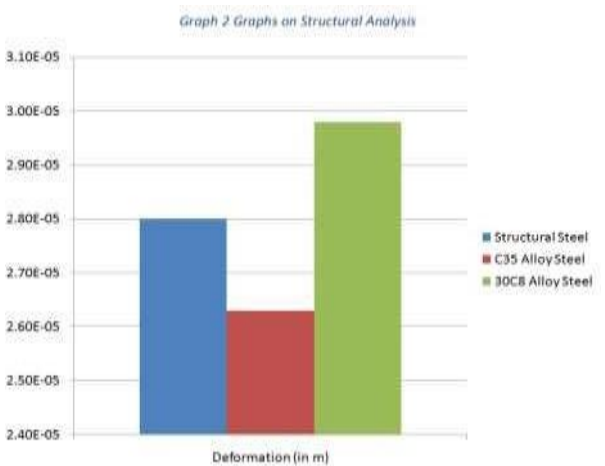
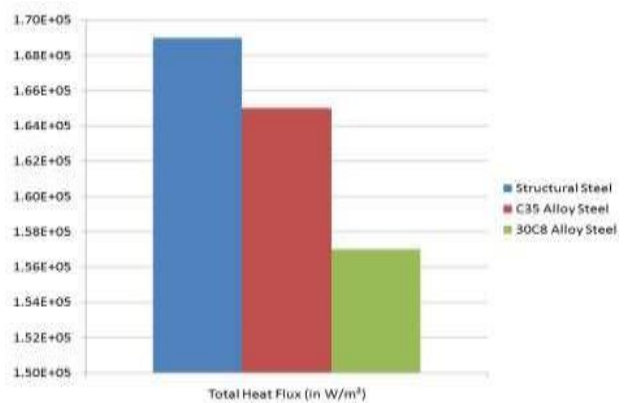
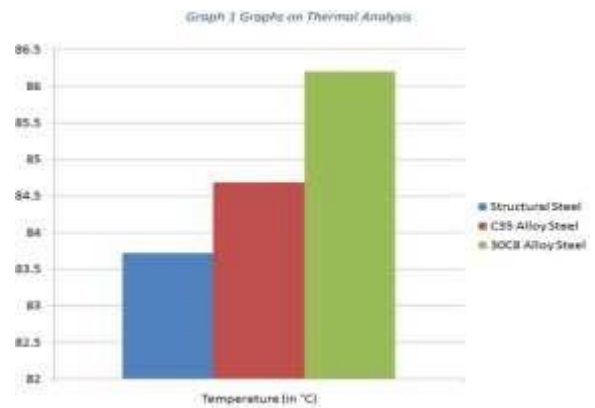
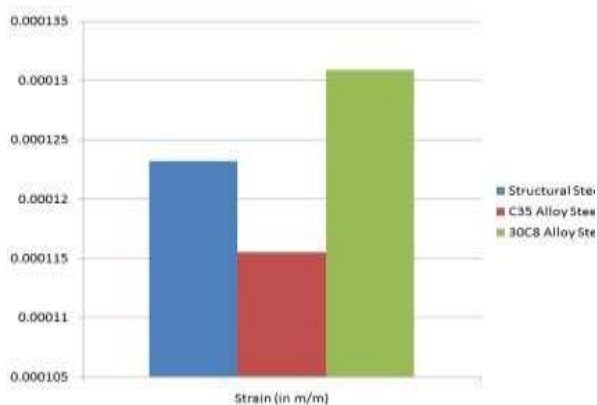
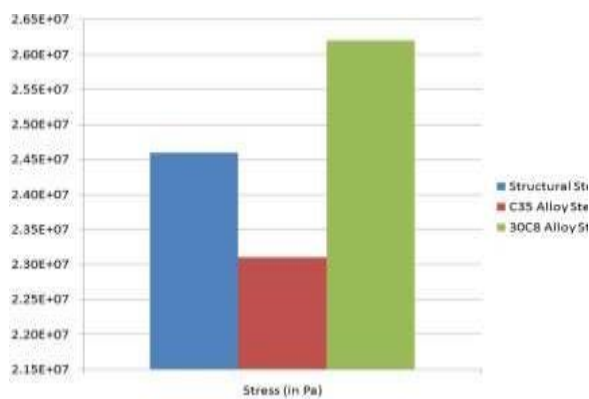
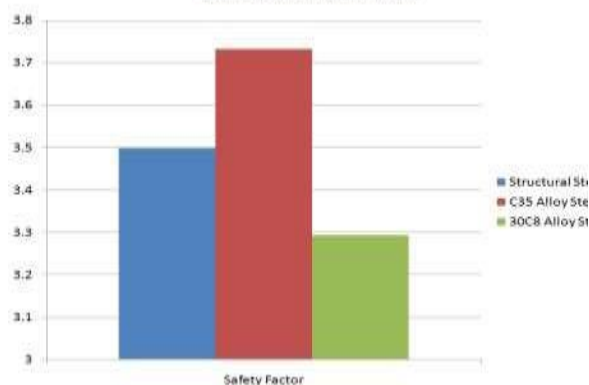


Fig: 21 SB - 30C8 - Fatigue - Safety Factor Representation of Results in Graphs

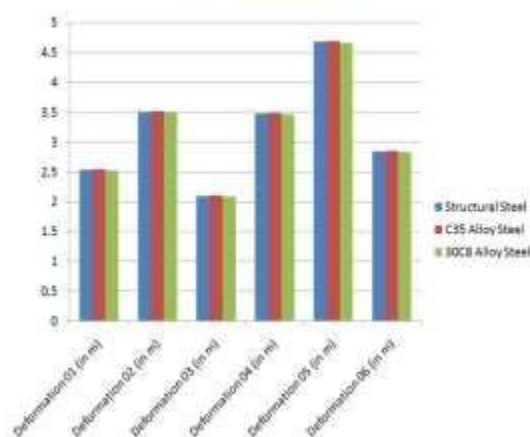




Graph 3 Graphs on Fatigue Analysis



Graph 4 Graphs on Modal Analysis



CONCLUSIONS

Because of this, we now know where inside a curve the Structural Analysis of a Steering Bracket should be applied with pinpoint accuracy. Above you can see Ansys output for the Steering Bracket design, including mesh results and displacement solution plots. This illustrates that there is some wiggle room in all the components. At the moment of fixation, the Von Mises stress was at its highest, also called the maximum safe stress. A price that is much less than the yield value. The structural nature of our major deliverables in Ansys workbench. The maximum strain was found to be rather little after solving the issue using the Ansys approach.

Analysis Type	Results	Structural Steel	C35 Alloy Steel	30C8 Alloy Steel
Thermal Analysis	Temperature (in °C)	83.717	84.69	86.201
	Total Heat Flux (in W/m²)	1.69E+05	1.65E+05	1.57E+05
Structural Analysis	Deformation (in m)	2.80E-05	2.63E-05	2.98E-05
	Stress (in Pa)	2.46E+07	2.31E+07	2.62E+07
	Strain (in m/m)	0.0001232	0.0001155	0.0001309
Fatigue Analysis	Safety Factor	3.4984	3.7317	3.2926
	Stress (in Pa)	2.46E+07	2.31E+07	2.62E+07
Modal Analysis	Deformation 01 (in m)	2.5353	2.5434	2.5272
	Deformation 02 (in m)	3.5048	3.516	3.4937
	Deformation 03 (in m)	2.096	2.1018	2.0884
	Deformation 04 (in m)	3.4763	3.4875	3.4653
	Deformation 05 (in m)	4.6795	4.6945	4.6647
	Deformation 06 (in m)	2.8435	2.8526	2.8345

Table 7 Comparison of Results

The results show that the C35 material has the lowest amount of deformation (2.63E-05 m) and the highest Safety Factor (3.7317) when subjected to an 800N pressure. C35 Alloy Steel is a popular carbon steel for fabricating a wide range of mechanical parts. Strength-in-forging superiority. Unique variants may be used for cold sketching. Because of the presence of carbon, welding calls for both preheating and post heating.

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