

DESIGN AND ANALYSIS OF AUTOMOBILE CHASSIS

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ABSTRACT: *This project provides a thorough overview of the design and development considerations for Heavy Vehicle Hybrid chassis. The proper design methodology for the development of a series-hybrid vehicle chassis is explored. Next, several loading scenarios are investigated in order to understand the substantially increased forces that must be communicated through the chassis and suspension components due to the added mass of hybrid apparatus such as electric motors and battery arrays. Material selection will also be considered. Utilizing 3-D modelling software, several design iterations are run in order to determine the best compromise between vehicle mass, component packaging, and weight distribution while still ensuring driver safety. This Project first covers the numerous loading conditions imparted upon the chassis during high speed, dynamic events. Moreover, the proper design methodology that should be considered when developing any high performance chassis will be explored. Next, the proper means of transferring these loads through the chassis structure will be discussed.*

Keywords: Chassis.

I. INTRODUCTION

The idea of a chassis carries several different connotations, depending upon the referenced source. For the purpose of this paper, the chassis will be thought of in its racing context as a structure which carries and connects all of the major components including the engine, driver, drive train, and other vehicle systems. The chassis structure must safely support the weight of the vehicle components and transmit loads that result from longitudinal, lateral, and vertical accelerations that are experienced in a racing environment without failure. There are many aspects to consider when designing a chassis, including component packaging (including the driver), material selection, strength, stiffness and weight.

The primary objective of the chassis is to provide a structure that connects the front and rear suspension without excessive deflection. When considering a race car chassis, a frame that is easily twisted will result in significant handling problems. Suspension setup is based upon the assumption that all four corners of the vehicle are connected by an infinitely rigid body. If the chassis is not sufficiently stiff, the structure is merely another variable in the system as it acts as a torsional spring. This variability within the chassis structure makes it very difficult to dial in a suspension setup that will generate the necessary levels of lateral grip to be competitive. Generally speaking, a frame that is able to resist torsional loads resulting from inertial accelerations of components experienced during cornering or from applied loads acting on one or opposite corners of the vehicle will almost always be sufficiently strong.

Automotive chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies, brakes, steering etc. are bolted. The chassis is considered to be the most significant component of an automobile. It is the most crucial element that gives strength and stability to the vehicle under different conditions. Automobile frames provide strength and flexibility to the automobile. The backbone of any automobile, it is the supporting frame to which the body of an engine, axle assemblies are affixed. Tie bars, that are essential parts of automotive frames, are fasteners that bind different auto parts together.

Automotive frames are basically manufactured from steel. Aluminium is another raw material that has increasingly become popular for manufacturing these auto frames. In an automobile, front frame is a set of metal parts that forms the framework which also supports the front wheels. It provides strength needed for supporting vehicular components and payload placed upon it. Automotive chassis is considered to be one of the significant structures of an automobile. It is usually made of a steel frame, which holds the body and motor of an automotive vehicle. More precisely, automotive chassis or automobile chassis is a skeletal frame on which various mechanical parts like engine, tires, axle assemblies; brakes, steering etc. are bolted. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis. Automobile chassis is usually made of light sheet metal or composite plastics. It provides strength needed for supporting vehicular components and payload placed upon it. Automotive chassis or automobile chassis helps keep an automobile rigid, stiff and unbending. Auto chassis ensures low levels of noise, vibrations and harshness throughout the automobile. The different types of automobile chassis include:

Ladder Chassis: Ladder chassis is considered to be one of the oldest forms of automotive chassis or automobile chassis that is still used by most of the SUVs till today. As its name connotes, ladder chassis resembles a shape of a ladder having two longitudinal rails inter linked by several lateral and cross braces. **Monocoque Chassis:** Monocoque Chassis is a one-piece structure that prescribes the overall shape of a vehicle. This type of automotive chassis is manufactured by welding floor pan and other pieces together. Since monocoque chassis is cost effective and suitable for robotized production, most of the vehicles today make use of steel plated monocoque chassis. **Backbone Chassis:** Backbone chassis has a rectangular tube like backbone, usually made up of glass fibre that is used for joining front and rear axle together. This type of automotive chassis or automobile chassis is strong and powerful enough to provide support smaller sports car. Backbone chassis is easy to make and cost effective. Chassis is one of the important parts that used in automotive industry. This structure is the bigger component

in the vehicle as shown in Figure. The chassis of trucks is tasked to hold all the components systems together such as the axles, suspension, power train, brake system, cab and trailer etc., while driving and transferring vertical and lateral loads caused by accelerations. The frame and other components not only carry the weight of the vehicle, but its payload as well. The chassis structure must safely support the weight of the vehicle components and transmit loads that result from longitudinal, lateral, and vertical accelerations that are experienced in a racing environment without failure. There are many aspects to consider when designing a chassis, including component packaging (including the individual systems), material selection, strength, stiffness and weight.

The most significant issue in the truck manufacturing industries is design of vehicles with more pay load. Using higher strength steels than the conventional ones are possible with corresponding increase in pay load capacity. Along with strength, an important consideration in chassis design is to have adequate bending and torsional stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis.

An important aspect of chassis design and analysis is the stress distribution and fatigue life of prediction process. Automotive designers need to have complete understanding of various stresses prevalent in different areas of the chassis component.

The stress analysis is important in fatigue study and life prediction of components to determine the highest stress point commonly known as critical point which initiates to probable failure, this critical point is one of the factors that may cause the fatigue failure. The magnitude of the stress can be used to predict the life span of the chassis. The location of critical stress point is thus important so that the mounting of the components like engine, suspension, transmission and more can be determined and optimized



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VEHICLE LOADING

Before the chassis can be developed, it is first important to fully understand the primary loads that the vehicle structure must be capable of withstanding. These loads must be efficiently transferred through the structure so that the chassis will not be prone to mechanical failure.

Typically, four forms of vehicle deformation are recognized as being fundamental in chassis design:

- Lateral Bending
- Horizontal Lozenging
- Vertical Bending
- Longitudinal Torsion

LATERAL BENDING

Lateral bending loads are often the result of centrifugal or inertial forces that are imparted on the vehicle as it attempts to navigate a corner at high speeds. The magnitude of this force is dependent upon vehicle speed, corner radius, and banking. Lateral bending may also result from strong winds acting on the side of the vehicle. Lateral bending loads act along the length of the vehicle and thus deformation will be greater with increased vehicle length, all other things being equal.

Lateral bending loads are resisted by the tires, but generally are not of primary concern as the following deformation modes lead to structural deflections of greater severity.

HORIZONTAL LOZENGING

In some instances, one side of a moving vehicle may have greater traction than the other. For instance, under heavy braking one tire may lock up and skid while the other continues rolling. This will impart an unequal horizontal force to the left and right sides of the vehicle, causing the structure to distort from a rectangular to diamond shape when viewed from above. In comparison to vertical bending and longitudinal torsion, however, lozenging is viewed as being of only minor concern based upon modern construction practices.

VERTICAL BENDING

Perhaps the second most important group of loads that must be distributed throughout the chassis structure are the vertical loads presented by masses including the driver, internal combustion engine, electric generator, motors, battery arrays, motor controllers, and fuel tank. In a static position, the sum weight of all these components, about 600 lbs, must be supported by the chassis. However, the dynamic loads of the vehicle must also be considered. As a moving vehicle passes over a vertical bump, the components of the vehicle will be accelerated upwards. This vertical acceleration will magnify the load experienced by the chassis structure. For instance, at rest a battery array represents a load of 50 lbs that must be transmitted from the battery mounts to the spring mounts through the tubular frame. However, when the vehicle experiences a 1 g bump, an inertial load of 100 lbs must be carried from the battery pack mounts to the spring mounting points.

Vertical accelerations of vehicle components tend to stretch the lower members of the chassis, loading them in pure tension, while the upper rails are compressed. Due to the fact that members loaded in tension are far less likely to fail than members experiencing compressive forces, which can lead to buckling, the lower rails of a chassis are often constructed of smaller outer diameter tubing or tubing with a thinner side wall.

LONGITUDINAL TORSION

The greatest loads that a chassis must resist are those that are torsional in nature. Torsional loads attempt to twist one end of the structure in relation to the other. As was stated previously, the goal of the suspension is to keep all four tires flat on the ground in order to maximize tire contact surface area and subsequently vehicle performance. In addition to poor vehicle handling, a chassis that constantly experiences twisting may fatigue over time and subsequently fail over repeated loading cycles.

Torsional loads arise from a variety of situations. The most simplistic form of torsional loading is the single wheel bump model, where one wheel passes over a bump and the other three remain at their original vertical orientation. This applied load from the upward movement of one wheel applies a torque to the chassis structure. The torsional stiffness of the structure can be defined by how much a frame will flex or distort when loaded in pure torsion, measured in foot-pounds per degree of rotation.

This is not to be confused with the strength of the structure, which is a measure of how much load the structure can handle before experiencing failure. Generally speaking, a chassis that is stiff enough to provide a stable platform for competition will not yield to applied stresses, given that all components are properly attached at triangulated junctions.

DESIGN METHODOLOGY

During the initial design stages of a heavy vehicle chassis, it is first important to consider what components must be included in the final vehicle system. The general layout of the vehicle systems should first be established, and then structural members of the chassis should be designed to connect the components at their mounting points. Therefore, the chassis conforms to the shape and location of the components, including the engine mounts, drive train, seat, suspension links, and so on. If the chassis is designed the other way around, that is the components are placed according to the chassis design, then the structure will have many inherent engineering flaws. It is essential that the components are connected in the most efficient manner possible, which means developing a structure that is capable of withstanding the loads imparted upon it while using the least amount of material possible and thus reducing vehicle mass.

COMPONENT PACKAGING

As a basis for chassis design, the track width and wheelbase must first be determined. Track width is defined as the lateral distance between the right and left wheel centrelines for the vehicle. Increasing track width helps resist the rolling moment of the vehicle caused by the inertial forces of vehicle components at the vehicle's centre of gravity. However, too wide a track will make it difficult to navigate the narrow courses that will be encountered during the competition. For a front track of 124.4 cm and a rear track of 117.5 cm were chosen. The rear track was made slightly narrower in order to reduce the risk of incurring time penalties due to cones being knocked over. One final determining factor of our track width was the specifications of a laser alignment tool that we had access to.

Once the wheelbase and track widths were determined, dimensions of major components including the internal combustion engine, generator, electric motors, suspension apparatus, battery arrays, drivetrain, and most importantly the driver were considered. Several sketches and model mock-ups were developed in order to estimate overall vehicle weight distribution and centre of gravity placement, as these factors are key in vehicle handling and performance.

VEHICLE PLATFORM

Perhaps one of the most critical decisions to be made by any team is what type of structure to develop. Due to cost considerations imposed by the Formula Hybrid Rules and ease of fabrication, it was decided that a tubular space frame chassis would be built instead of a composite monocoque employing composite sandwich construction. A space frame is a 3-dimensional structure that is assembled such that its members are only subjected to loads that act along the

lengthwise axis of the tube, meaning the tubular members are theoretically free from bending loads. This design is highly efficient as thin-walled, tubular pipe exhibits high strength in compression and tension, but performs very poorly when subjected to bending loads. Although it is often difficult to ensure that all members will be free from bending loads, a chassis that approximates the ideal as closely as possible will yield the most desirable results.

TRIANGULATION

With the application of space frame construction, it is desirable that all loads enter the structure at points of intersection of at least three tubular members. These loads may arise from components being accelerated in a given direction or from forces transmitted through the front and rear independent suspension components. In order to ensure that members are loaded purely in compression or tension, proper triangulation is essential. Triangulation serves as the simplest method to isolate loads experienced by chassis members to compression and tension. When a load is applied to a triangular structure, two of the members stretch the third, loading it in pure tension. Thin-walled tubing functions best when loaded in tension the material is not susceptible to the risk of buckling, as is the case when the tube is loaded in compression.

Proper engineering practices dictate that all major components be attached to the structure at triangulated nodes. This is especially important at suspension pickup points and engine mounting tabs where some of the greatest loads are transferred throughout the structure.

LOAD PATH

Once a general component layout is established and structural members are being added, it is important to consider that loads within a chassis are not merely absorbed by the structure, as is commonly thought.

Although loads may be more concentrated in certain areas than others, such as spring mounting points, the main purpose of the chassis structure is to transmit a load from one point to another while all members are loaded in pure tension or compression. This notion of the structure conveying loads from one point to another is commonly referred to as the structure's load path.

The load path is the route through which forces are fed through the chassis structure. Load paths should be as direct as possible while still providing adequate structural stiffness, to be explained shortly. All reactions from these loads are generally taking up at the tire contact patch if the structure is designed with good practice.

SOLID MODELING

After determining basic design requirements, including preliminary suspension geometries, a 3-dimensional computer model can be generated in order to better visualize how the structure will come together. Once again, the structure must conform to the placement of the components, and not the other way around. For a chassis design is chosen to use the PRO-E 3-D Modeling Software. This software was chosen as it very user friendly and allows material parameters

to be specified, which is helpful in predicting vehicle mass, weight distribution, and centre of gravity location.

After having previously determined a general requirement for track and wheelbase parameters, suspension control arm mounting points can be entered into the software as a basis of construction. From here, lines were drawn based upon the location of vehicle components and the specifications. These rules specify outer tubing diameters and sidewall thicknesses of safety critical components such as the roll hoops (main and front), side impact structures, and roll hoops supports.

During the modeling process, it is important to keep in mind essential engineering practices such as triangulating tubular members at all nodes and optimizing load paths. Solid models of main components such as the engine, electric motors, battery arrays, and rear CVT's must be incorporated when designing the structure to ensure proper clearance and mechanical function. It is also important that an adequate level of clearance is provided between the top of the driver's head and the main roll hoop for safety concerns. The rules specify that at least two inches of clearance must be maintained between the top of the head of the 95th percentile male (measured by template) and roll hoops.

It is essential that driver ergonomics be considered when designing the frame. If the driver is not situated properly and does not have easy access to vehicle system controls, then he/she will not be able to operate the vehicle to the limit of its capability. After all lines are drawn for the frame connecting the different systems of the vehicle, the Structural Members feature of the PRO-E software can be utilized to input individual member parameters, including material properties, tubing outer diameter and sidewall thickness.

Analyzing the initial frame design, the extensive use of triangulation at all suspension pickup points is clearly visible. This is especially evident at the front of the chassis, where the use of tetrahedral structures was used in order to transfer lateral loads from the upper control arms to the chassis more efficiently. The suspension bell cranks were mounted at extensively triangulated nodes about which they will rotate. A central node was incorporated in the frame above where the driver's legs are positioned. This node will serve as a strong central loading point where the spring/damper coil over units of the suspension will mount.

Finally, the main roll hoop supports came under scrutiny. We felt that the two extended, continuous members that compromised the main roll hoop support were prone to buckling and lacked proper triangulation. This would severely hamper vehicle performance by limiting torsional stiffness. A design solution was created in which the main roll hoop support was divided up into several members, allowing for more extensive use of tetrahedral structures, the stiffest 3-D element. These structures would greatly increase the torsional stiffness of the rear of the chassis and subsequently improve vehicle performance. Moreover, the new design allowed for a central loading point for the rear suspension.

II. CONCLUSIONS

In the present work, ladder type chassis frame for TATA Turbo Truck was analyzed using ANSYS 14.5 software. From the results, it is observed that the Rectangular Box section is having more strength than C and I Cross-section type of Ladder Chassis. The Rectangular Box Cross-section Ladder Chassis is having least deflection i.e., 2.96 mm and least Von Mises stress and Maximum Shear stress i.e., 54.31MPa & 5.98MPa respectively for Aluminium Alloy 6063-T6 in all the three types of chassis of different cross section. Finite element analysis is effectively utilized for addressing the conceptualization and formulation for the design stages. Based on the analysis results of the present work, the following conclusions can be drawn.

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