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A Review on Utilization of Computer-Aided Design/Manufacturing Software in the Production of a Three-Wheeler Chassis

Shrikant D Yawalkar[1], Srinivasa Rao Pulivarti[2]

[1,2] Department of Mechanical Engineering Christian College of Engineering & Technology, Bhilai, India

shrikantyawalkar88@gmail.com, srinivas.indore@gmail.com

Corresponding author: shrikantyawalkar88@gmail.com

Abstract: Currently, three-wheeler chassis are unheard of in the automobile business. It can be difficult to incorporate the characteristics of a conventional four-wheeled chassis into a three-wheeled chassis on a regular basis. It the present analytical study is to design and construct a three-wheeled chassis that can be used in real-time conditions. A computer-aided design (CAD) and computer-aided manufacturing (CAM) software package were proposed to be used to create the chassis in accordance with the specifications. This three-wheeled vehicle will serve as a substitute for two-wheeled vehicles in certain situations. According to the tadpole design, the vehicle will have two wheels up front and one wheel in the back. Because it is a perfect fit between the motorcycle and automobile categories, the vehicle must adhere to both motorcycle and automobile laws.

Keywords: Chassis, Dynamic stability, Mild steel, Torsional rigidity, CAD and Tadpole design

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1. Introduction

Since the beginning of human history, mankind has strived to make life easier for itself and others, and automobiles have played a significant role in this endeavor. Because of the rapid growth in population and the increasing number of vehicles, car designers are required to not only build small and fuel-efficient vehicles, but they are also required to inspire the next generation of engineers to pursue careers in this sector of automotive engineering in order to reap the benefits of their efforts. In this regard, a large number of compact automobiles are being introduced, and three-wheeled vehicles, for example, are becoming increasingly popular for city commuting due to their lower fuel consumption, ease of operation, and availability of parking in most nations worldwide [1]. Regardless of their widespread use, three-wheelers have a significant drawback: they lack stability on rough terrain. There has been a great deal written about how to improve its stability, but only two ways have been shown to be effective: tilting the system and cambering. Tilting is utilized for maneuvering and quick driving, while camber is used for normal commuting in cities, depending on the requirements of the vehicle [2].

The chassis of a vehicle is the most significant component of the vehicle. It is the physical frame or structure of a vehicle to which all other components are joined, and it can be thought of as akin to the skeleton of a living thing in terms of appearance. Chassis frame is where all of the vehicle's components are mounted, including the axles and wheels and tyres as well as the suspension, a controlling system such as braking, steering, and so on, as well as the electrical systems [3]. The term "chassis" comes from the French language and was originally used to refer to the frame parts or basic framework of a vehicle. It serves as the vehicle's structural support. Chassis is the name given to a vehicle that does not have a body. Vehicle components such as the engine, transmission system, axles, wheels and tyres, and suspension are all discussed in detail. Controlling systems such as braking, steering, and other similar functions, as well as electrical system components, are situated on the chassis frame. It is also referred to as the "Carrying Unit" because it serves as the primary mounting point for all of the components, including the body. The cost of tooling will be greater due to the fact that we will be using two separates chassis for passenger and load carrying vehicles. The objective was to create a single chassis that could be used for both types with just minor alterations. This was constructed from a passenger vehicle chassis by adding some more material in the appropriate places, but it meets the purpose of a carrier vehicle. As a result, it will almost certainly lower the cost of tooling while also raising the manufacturing rate.

1.1 Chassis material

In this article, we'll take a quick look at some of the most common materials used in cars today. Materials should be weighed in relation to one another, and the yield strength of each material should be mentioned. Yield strength is the greatest stress that can be given to a body before it permanently changes shape.

1.1.1 Advanced High Strength Steel

Several categories exist for steels used in the automotive industry. Low strength steels (such as interstitial-free and mild steels) and traditional high-speed steels are two of the most common varieties (carbon manganese, bake hardenable and high-strength, low-alloy steels). With so many variants available, it has become the go-to material for cars. Depending on its intended use, some varieties of steel might fetch a much higher price than others. In order to achieve the desired properties, Advanced High- Strength Steels (AHSS) go through a multi-stage heating and cooling process. Its exceptional strength, ductility, toughness, and fatigue characteristics are a direct result of this. AHSS is superior to mild steel because it is easier to work with and can be better adapted to the needs of the automotive sector. When the yield strength of a steel is 550 MPa or greater, it is referred to as an AHSS. Although AHSS are more costly than alloy steel or mild steel, they are less expensive than alternative materials with comparable strength properties [9].

1.1.2 Aluminium

Aluminum has been a standard vehicle material for many years. Lightweight, corrosion-resistant, highly ductile, highly mobile, and easily recyclable are just some of the many advantages of the material. Passenger vehicles employ the material in varying amounts, but it is predominantly used in those vehicles. You can find it in trace amounts in mass-produced cars like Toyotas, Nissans, and others. However, the material is the norm in the luxury car segment. Although aluminum's yield strength reaches 310 MPa, it is still a very malleable metal. This combination of malleability and strength is what makes aluminium such a useful and flexible material. It's strong and durable, but can be moulded into any shape a manufacturer needs. Aluminum's high cost discourages many original equipment manufacturers from using it, especially in larger vehicles like buses and heavy-duty trucks [10].

1.1.3 Magnesium

Magnesium alloys first appeared in the automobile industry in the 1920s, and quickly became popular in racing vehicles. Over the past decade, there has been a growing interest in using this material in commercial vehicles. Increasing environmental and political pressures are mostly to blame for this. It is one of the most recyclable materials available and is 34% lighter than aluminium, another lightweight metal. Magnesium's high malleability and moderate strength make it suitable for the manufacture of a variety of automobile parts. You'll frequently find it in places like gearboxes, steering columns, cover plates, and more. Its low yield strength of up to 300 MPa disqualifies it from employment in load-bearing structures and, more specifically, in larger vehicles like buses and lorries. The cost, which can be twice that of Aluminum, is another barrier that prevents its widespread application [11].

2. Literature Review

When designing an automobile chassis, prior understanding of the various conditions the chassis is most likely to face is of great importance.

Kenji Karita, et. al. [15] has designed a chassis built from Aluminium. The material 6061-T6 was chosen to be the frame's primary constituent. When it came to the construction of the chassis, they opted to make use of the variable section extrusion process. Computer-Aided Engineering was utilised throughout the creation of this product. The use of aluminium material has the benefit of reducing overall weight. According to the findings of this research conducted by the authors, the aluminium chassis achieves the desired levels of weight reduction, strength, and stiffness. In addition, they came to the conclusion that the outstanding technological challenges would be resolved in order to permit the commercial use of the aluminium frame.

The chassis of the Hyundai Cruz Minibus was researched and examined by Alireza Arab Solghar et. al. [16]. The modelling and simulation work was done with the ABAQUS software. When doing the static analysis, the self-weight of the chassis is taken into account. When performing the dynamic analysis, however, acceleration, braking, and road roughness are taken into account. It was discovered that the loads placed on the chassis as a result of braking were significantly higher than those created by acceleration.

M. Ravichandra, et. al. [17] conducted research on a different material that might be used for the chassis. They investigated and examined Carbon/Epoxy, Eglass/Epoxy, and S-glass/Epoxy as chassis materials in a variety of cross sections, including C Section, I Section, and Box Section. The chassis of a TATA 2515 EX was seized for inspection. In order to complete this task, the software packages Pro-E and Ansys were utilised. A comparative study shows that the Carbon/Epoxy I section chassis outperforms other materials and cross sections in terms of its tensile strength, torsional rigidity, and overall weight.

FEM stress analysis was employed by Roslan Rahman et. al. [18], as preliminary data for fatigue life prediction. They conducted their simulations and analyses with the ABAQUS programme, and they researched the properties of the ASTM Low Alloy steel A710 (C) material. The primary mission was to identify the high-stress region where the fatigue failure will first manifest itself. It has been discovered that the area of the chassis opening that is in contact with the bolt is subjected to severe stress.

The authors N.V. Dhandapani et. al. [19] employed finite element methods in conjunction with Ansys software to conduct their research on the influence of different stress distributions. They installed gussets in the failure region of the 100-ton dumper so that they could study the failure that occurred in the field. When the structure of the chassis was tested after being modified, using linear static analysis, it was discovered that the redesigned chassis was safe to use.

Teo Han Fui et. al. [20] investigated the effects of road roughness and excitations on the 4.5 Ton truck chassis. The vibration that was caused by Road Roughness as well as the excitation that was caused by the vibrating components that were installed on the chassis were both analysed. The reactions of the chassis were analysed by looking at the stress distribution and displacements. The findings of analysing the mode shape allow for the determination of the optimal mounting positions for components such as engines and suspension systems.

S.S. Sane et. al. [21] used finite element modelling (FEM) to conduct an analysis of the light Commercial Vehicle chassis and to mimic the failure that occurred during testing. For both analysis and simulation, the software packages Hyper mesh and Opti-struct were utilised. During the course of the investigation, they implemented local stiffeners with the goal of lowering the total amount of stress. The stress values of the upgraded chassis were decreased by a factor of 44%.

Static structural analysis was used to research the Eicher E2 ladder chassis frame by Vijaykumar V. Patel et. al. [22]. In the context of this study, a chassis was conceptualized as a simply supported beam that had an overhang. In order to complete this task, the software packages Pro-E and Ansys were utilised. In addition to that, the analytical calculation of chassis was a part of the investigation. When the results of analytical computation and software analysis were compared, it was discovered that the stress value derived from software analysis is 10 percentage points higher, and the displacement was likewise 5.92 percentage points higher.

By utilising the Finite Element method, Kutay Yilmazcoban et. al. [23] were able to conduct research on and optimise the thickness of an intermediate tonnage truck chassis. The primary goal of this study was to cut down on the amount of material used, which would ultimately result in a reduction in the amount of money spent on materials. They contrasted the findings of analysing three different thicknesses of material used for the chassis in terms of stress and displacement. According to the findings of the study, a thickness of 4 millimetres is reliable enough to support 15 tonnes of weight.

N.K.Ingole et. al. [24] examined the Tractor Trailer that was manufactured by Awachat Industries, Wardha in order to find ways to lower the cost of production. The Ansys Programme was used to do an analysis on the four different modified trailer designs that were created in the Pro-E software. When the results of four various designs of trailer chassis were compared, it was determined that the fourth design was the most weight-efficient design. It has been hypothesized that the fourth type of trailer chassis was one that could accommodate mass manufacture and was also economical.

The failure of the longitudinal stringer of a vehicle was investigated by V. Veloso et. al. [25]. During the durability test, failure was noticed at the areas of the vehicle suspension that were located near the bumpers. The first crack was produced and has since expanded, which has caused the component to shatter. They looked at six different kinds of reinforcement in order to find a solution to this issue. Through the use of hyper mesh software, each of the six different forms of reinforcement methods were studied, and the results proved that the sixth type of reinforcement offered superior outcomes. On the basis of the software results, the laboratory test had been carried out, and the failure had not been seen. They were able to acquire better findings in a shorter amount of time by using the software analysis to replace a number of the necessary laboratory procedures. This results in a significant reduction in the expenses associated with testing.

Using multi-body dynamics, Yongjie Luet. et. al. [26] have created a virtual prototype model of a heavy-duty vehicle (DFL1250A9). Both the shock absorber and the leaf springs have their geometric structural parameters as well as their nonlinear properties properly determined. The dynamic model was shown to be correct after the testing data were compared to it. According to the findings of the study, the testing data and the model of the virtual prototype car were quite similar. The study also found that an increase in running speed may cause damage.

Researchers Ojo Kurdi et. al. [27] investigated the effects that road roughness has on the distribution of stresses in large vehicle chassis. In order to cut costs and ensure an optimal design, they used software called finite element analysis to conduct an analysis of both static and dynamic circumstances. The load was modelled as a constant pressure that was calculated by dividing the maximum loaded weight by the total contact area that existed between the cargo and the upper surface of the chassis. This formula was used to estimate the load. In order to get a more satisfactory outcome, locally finer meshing was implemented in the area that was thought to have the highest levels of stress. It has been determined via research that the static loading that constitutes the majority of the burden placed on the truck chassis originates from the cargo and the contents of the cargo. The uneven surface of the road has not had a major impact on the stress placed on the component.

The chassis of the Hyundai Cruz Minibus was analysed and investigated by Alireza Arab Solghar et. al. [28]. Modeling and simulation were accomplished with the help of ABAQUS Software. When doing the static analysis, the self-weight of the chassis was taken into account. When performing the dynamic study, however, acceleration, braking, and road roughness were taken into account. It was discovered that the loads placed on the chassis as a result of braking were significantly higher than those created by acceleration.

The Finite Element Method was utilised by Cicek Karao et. al. [29] in order to conduct an analysis on a vehicle chassis with riveted joints. For the purpose of finding a solution to the issue, the proprietary finite element software tool known as ANSYS version 11.0 was utilised. The thickness of the side members, the thickness of the connection plates, and the length of the connection plates were all subject to variation in order to meet the goal of lowering the magnitude of the stress at the riveted junction of the chassis frame. According to the findings of the numerical analysis, the stresses imposed on the side member can be mitigated by increasing the thickness of the side member.

Zhongzhe D. et. al. [30] have conducted fatigue life analysis and enhancement of the auto body in an SUV (SUV). The finite element (FE) approach was utilised in order to get the stress distribution after unit displacement excitation had been applied. In order to provide load spectra in compliance with the vehicle reliability test, a bilateral track model was selected as the appropriate representation. As a result of using the nominal stress approach under the presumption of a uniaxial stress condition, the entire life expectancy of the vehicle's body was calculated, and the crucial sections were then identified. On the basis of multi-axial fatigue theory, further research was conducted into the life expectancy of components that featured key zones. The findings indicated that components located close to the suspension had been harmed as a result of impact loads from the road. In order to increase the fatigue life of the component, topological optimization of the spot weld placement in the crucial region was performed using the homogenization approach.

K. Chinnaraj et. al. [31] have decided to optimise the weight of the chassis frame assembly of a big vehicle that is utilised for delivering commodities over long distances. The dynamic stress-strain response of the component as a result of various motions, such as braking and cornering, was experimentally monitored and reported. In order to carry out the numerical simulation, a quasi-static approach was followed. This approach approximates the dynamic manoeuvres into a number of small processes that have static equilibriums, and it was followed to approximate the dynamic behaviour of the frame rail assembly during cornering and braking. In order to carry out the quasi-static numerical simulations, the commercial finite element software ANSYS was utilised. The findings of these simulations were then compared to those of the experiments. The study assisted in gaining a knowledge of the predominant stresses that are placed on truck frame rails, particularly during braking and turning movements, and it identified all geometric places that have the potential to become points of failure.

3. Results and Discussions

These days, most car manufacturers focus on enhancing three main areas to boost fuel efficiency. Most original equipment manufacturers have done extensive research on electrification, sophisticated engine technology, and lightweight design to reduce their vehicles' negative effects on the environment. Given that the airport shuttle will be electric and driverless, minimising its weight is another strategy for lessening its negative influence on the environment. At the outset of automobile development, lightweight metals like magnesium and aluminium were favored over heavier metals like cast iron and steel. But advanced high strength steel (AHSS) developed as a new lightweight material, and it has recently become generally accepted by most of the OEMs due to its strength, production cost, and new advancements in the manufacturing process that allow for mass production of the material.

The high cost of lightweight materials like magnesium, aluminium, advanced composite materials, etc., as compared to ordinary steel alloy, is one of the key problems with using these materials. The price of carbon fibre epoxy and advanced composite materials may be anywhere from $11 to $33 per kilogramme of total weight, whereas the price of aluminium and magnesium can be anywhere from $3 to $22 per kilogramme. To reduce negative effects on the environment, it is necessary to take into account a number of aspects beyond just the price tag. It takes a lot of energy to produce materials including carbon fibre, magnesium, glass-fiber composites, advanced composites, and aluminium, with metal being the least energy extensive of them. The phases of extraction and production use the most energy. Many academic organizations put more emphasis on studying how a vehicle performs in actual use, and less on how much energy and greenhouse gases are released during the extraction and production of its components. This might cause people to favour some materials over others. It might be challenging to select durable and eco-friendly materials for use in various auto parts. It's not uncommon for original equipment manufacturers to have to negotiate competing priorities. Magnesium and aluminium, for instance, are lightweight and hence minimise the amount of energy needed for traction during the usage phase, but they are also costly and energy-intensive to mine and refine. Although CFRP and GFRP have desirable properties such as low mass, high strength-to-weight ratio, and low density, their widespread usage in the automotive sector is hampered by their complex production process and expensive costs.

When designing the chassis, it's vital to balance a number of factors, including strength, rigidity, ergonomics, space, and weight. The allotment of space for batteries is crucial since the vehicle will be electrically powered by batteries. Due to the massive number of batteries (126 liters) needed for the vehicle, they must be spread out across a wide region. This eliminates the potential for the vehicle to have mass concentrations that might cause uneven distributions of cargo. To achieve a low centre of gravity, the batteries should likewise be positioned low to the ground (CoG). The potential for a rollover should be reduced because the vehicle will not be driven at high speeds or around sharp turns.

3. Conclusions

It has been known, based on the numerous research investigations that have been carried out up to this point, that the design of the chassis for vehicle begins with a consideration of the loads that are mostly operating on it. The vertical load that is caused by the pay load is the key concern for large transportation vehicles. To counteract the effects of this vertical load, the chassis needs to be able to resist the bending moment that is being applied to it.

All of these factors, as well as the sort of loads applied, will influence the overall design of the chassis, as well as the material used. If a chassis is built to be robust to bending, it may not be as resistant to torsion or other types of bending. As a result, it is critical to account for these factors during the design process in order for the finished product to be optimal for its intended use. With this in mind, there will be less of an impact on the environment.

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