e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:11/November-2022 Impact Factor- 6.752 www.irjmets.com

DESIGN AND ANALYSIS OF TUBULAR REAR TWIST BEAM STRUCTURE FOR HIGH SPECIFIC ROLL STIFFNESS

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DOI : https://www.doi.org/10.56726/IRJMETS31210

ABSTRACT

Light weighting is a concept in the auto industry about building cars and trucks that are less heavy as a way to achieve better fuel efficiency and handling. Carmakers make parts from high strength steels and innovative designs, as ways to lessen vehicle load. Also Global trends toward CO2 reduction and resource efficiency have significantly increased the importance of this topic over the last years. This study further to this topic is as designing the tubular close profile twist beam with high specific roll stiffness ratio. Basically it is a ratio of roll stiffness to weight. It is all about extracting higher dynamic and durability performance from the structural component with lesser weight. Torsion beam rear-suspension systems have recently been widely used for small passenger vehicles, because of various advantages, including a reduced weight, lower cost, and greater space efficiency, when compared with other types of suspension system. This subject consist entire design and development process of close profile twist beam with the objective of downsizing and improving the performance, integrating the child part or reducing the part count without any impact on the performance in the need of the hour to make it frugal. This objective is realized by smart and innovative design variable section closed profile Crossbeam against conventional bulky assembly of open profile crossbeam with number of child parts such as reinforcements and stabilizer bar. This innovative arrangement renders the thermal and residual stress by better distribution of welding across the assembly. The output of the subject structure will be the better stiffness compared to conventional open profile twist beam design that leads to a considerable saving in terms of weight, simplification of design, improvement in durability performance and manufacturing process. This study deals with roll stiffness calculation and Finite Element Analysis of the rear twist beam suspension system and its optimization through new concept design under static loading condition for high specific roll stiffness. The existing open profile twist beam from one of entry level hatch segment passenger car is selected for the study.

Keywords: Twist Beam Suspension, Specific Roll Stiffness, Light Weight, Tubular Twist Beam, Roll Stiffness.

I. INTRODUCTION

Suspension is the term given to the system of shock absorbers, spring and linkages that connects a vehicle ends to its wheels and allows relative motion between the two. It serves a dual purpose of contributing to the vehicle's road holding/handling and braking for good active safety and driving performance and keeping vehicle occupants comfortable and reasonably it isolated road noise, bumps, and vibrations. These goals are generally at odds, so the turning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because of all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself, and any cargo or luggage from wear and damage. The design of front and rear suspension of a car may be different type.

Rear Suspensions

The rear suspension should be ready to carry any extra masses placed within the rear of the vehicle whereas still maintaining the proper ride height. The rear suspensions on several front shaft weight and rear shaft weight vehicles area unit similar in this a solid style of shaft is employed. tho' robust, a solid shaft doesn't give the amount of handling associate degreed ride quality that an freelance rear suspension will. This will be troublesome since force tries to twist the vehicle and rear suspension. The purpose of the entire mechanical system is to isolate the vehicle body from road shocks and vibrations which might preferably be transferred to the passengers and cargo. It should conjointly keep the tires up-to-date with the road, despite paved surface. A basic mechanical system consists of springs, axles, shock absorbers, arms, rods, and ball joints. Basic sorts area unit leaf springs, coil springs, and torsion bars . Fashionable traveler vehicles typically use light-weight coil springs. Light-weight industrial vehicles have heavier springs than traveler vehicles, and might have coil springs at the front and leaf springs at the rear. The study of the forces at work on a moving automobile is termed vehicle dynamics. a number of the ideas area unit required to be understood so as to understand why a suspension is critical within the initial place. Most automobile engineers contemplate the dynamics of a moving automobile from these perspectives:

- Control spring and suspension movement
- Provide consistent handling and braking
- Prevent premature tire wear
- Help keep the tires up-to-date with the road
- Maintain dynamic wheel alignment
- Control vehicle bounce, roll, sway, drive, and acceleration squat
- Reduce wane different vehicle systems
- Promote even and balanced tire and brake wear

Ride – A car's ability to disembarrass a jarring road.

Handling – A car's ability to soundly accelerate, brake and corner.

Road Isolation – The vehicle's ability to soak up or isolate road shock from the traveler compartment. enable the vehicle body to ride undisturbed whereas traveling over rough roads. Absorb energy from road bumps and dissipate it while not inflicting undue oscillation within the vehicle.

Road Holding – The degree to that a automobile maintains contact with the paved surface in numerous styles of directional changes and during a line (Example: the load of a automobile can shift from the rear tires to the front tires throughout braking. as a result of the nose of the automobile dips toward the road, this kind of motion is understood as "dive". the other impact "squat" happens throughout acceleration, that shifts the load of the automobile from the front tires to the rear. This transfer of auto weight from facet to facet and front to back cut back the tire's grip on the road.

Cornering – it's the flexibility of a vehicle to travel a snaky path. Minimize body roll, that happens as force pushes outward on a car's center of gravity whereas cornering, raising one facet of the vehicle and lowering the other facet. Transfer the load of the automobile throughout cornering from the high facet of the vehicle to the low facet.

Types of Rear Suspension Systems

The two main kinds of suspension systems found in cars square measure dependent and freelance. The classification of wheeled suspension is as shown in figure [1]. These suspension systems additionally apply to alternative vehicles like semi-trucks. Every sort of suspension utilizes springs and shock absorbers. There square measure varied kinds of springs together with coil springs, torsion bars and leaf springs. If a vehicle solely had springs it might boat and wallow in conjunction with the road creating the ride terribly uncomfortable. Imagine the suspension simply mimicking what it's encountering on the road instead of interesting it. this can be wherever shock absorbers are available that square measure technically dampers. They absorb any larger than average bumps within the road, thus borderline motion is transmitted to the chassis. Additionally, shock absorbers keep the suspension at its most pass by pushing it towards the road, that additionally helps keeps your tires on the road. Several trendy cars have a coil-over-oil unit which includes each a muffler and spring into one product.

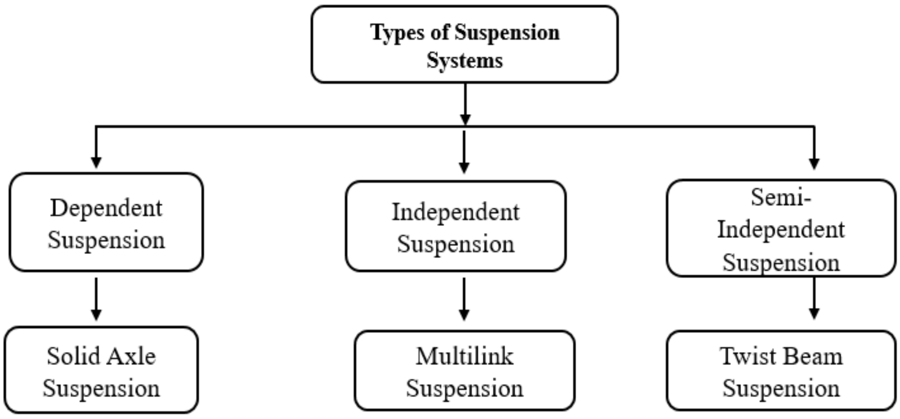


Fig 1. Types of rear suspension

II. LITERATURE REVIEW

A brief history of suspension field has been documented in the present review. It reviews early development of various types of twist beam designs and It also reviews design and developments, simulation of stress, strain and deformation analysis of a vehicle suspension system.

Mr. Amol Apte et. al. , "Virtual Development of Optimum Twist Beam Design Configuration for a New Generation Passenger Car" presents, It is customary to select a twist beam rear suspension for front wheel driven small and medium range passenger cars. Besides better primary / secondary ride comfort, roll stiffness tuning ability, ease of assembly & good packaging solutions than the conventional semi trailing arm/ rigid axle suspensions, twist beam suspension system accentuate the concentration required in placing & orienting the cross beam to achieve certain imperative kinematical characteristics. In order to make the solutions of the required kinematical targets viable, it is vital to have the packaging space and stress concentration within yield limits given the weight & cost targets. This paper presents the work done on twist beam type suspension for a new generation entry level B-Class hatchback vehicle developed. To reduce the time consumed in validation of different design proposals a virtual validation process was developed. Various twist beam design proposals were analysed by the virtual validation process consisting of durability and kinematic analyses. Kinematic analyses were done using flexible model of twist beam in ADAMS View Environment (AVE). Durability Load Cases (DLCs) were derived using the Road Load Data (RLD) collected using a representative prototype. This was done to make sure that the structural component sustains the specified life in the targeted market. In twist beam structure, geometric non-linear effects are crucial in the strength evaluations. MSC-NASTRAN (MN) non-linear analysis capabilities were used for strength evaluation.

Mr. G. Fichera et al "Modelling of Torsion Beam Rear Suspension By Using Multibody Method"consider when the multibody systems analysis has become one of the main simulation techniques to calculate the elasto-kinematics characteristics of a car suspension under wheel loads or to realize complex full vehicle models in order to predict the handling performances or the NVH quality. The modelling of torsion beam rear suspensions—widely adopted in cars belonging to B or C class presents some problems arising from the structural behaviour of this component. A linear method based on component mode synthesis was used to represent the flexible torsion beam within the multibody model. This kind of approach was compared with a non-linear FE analysis. The elasto kinematics analysis of the suspension was performed by using SIMPACK multibody code. The main suspension parameters (toe angle, camber angle, wheelbase and track variation) were calculated by changing wheel travel and loads. Static analyses, involving great displacements, were performed and a different number of modes were considered in the modal condensation of the torsion beam. The results of multibody simulations were compared with those obtained from a non-linear FE model. Different stiffness values of the bushings that connect the torsion beam to the vehicle chassis were taken into account.

Mr. K-J Mun1 et al "Analysis of the roll properties of a tubular-type torsion beam suspension" presents the proposed paper for an analytical method to calculate the torsional stiffness of a tubular beam with a closed cross-section in a torsion beam rear suspension system using linear beam theory. Also, a potential energy method is proposed to calculate the equivalent spring stiffness (or roll stiffness) at the wheel centre, based on considering the elastic effect of the torsional stiffness of the tubular beam, together with the torsional and conical stiffness of the rubber bushing. The results of the proposed analytical method showed good agreement with the results of an ADAMS simulation in which the flexible body effect was considered. Furthermore, since the proposed analytical method requires only the geometry of a tubular beam and bushing stiffness, it can provide immediate basic results on the roll properties of a torsion beam, making it an effective tool for design engineers during the initial design stage when there are so many design variables to consider, and which usually takes much time when using multi-body dynamic software, such as ADAMS.

Mr. Márcio Eduardo Silveira et al "Numerical Simulation of the Kinematic Behavior of a Twist Beam Suspension Using Finite Element Method" has concluded that the use of numerical simulations in the design of automotive components has contributed to reducing the design time, decreasing the prototypes costs and increasing reliability of the final product. In addition, the search for solutions of low cost and satisfactory performance is essential for the success of the product in the world market. Twist-beam suspensions are an example of this competitive environment. This solution presents a very satisfactory performance when applied to light vehicles and has an excellent relationship between cost / benefit in the automotive market. It is estimated that more than 90% of light vehicles manufactured in emergent countries use this type of suspension at the rear. Despite its acceptance in the automotive market there are few studies related to the twist-beam suspension, perhaps because of its simplicity and low cost design and ease of manufacturing. Unlike other types of suspension, the twist-beam has a flexible torsion beam connecting the swing arms. The evaluation of the deformation of this flexible element becomes essential to understand their kinematic behavior. Thus, the use of software based only on the rigid body dynamics is not suitable to analyze this type of suspension. The main objective of this work was to evaluate through numerical simulation based on finite element method, the influence of the torsion beam on the kinematic behavior of a twist-beam suspension. It was evaluated the influence of both the position and orientation of the torsion beam on the suspension, under symmetric and asymmetric loadings.

Mr. Benki Aalae et al "Computational design of an automotive twist beam" In recent years, the automotive trade has notable a motivating development so as to satisfy the client necessities. during this paper, we'll study one among the parts of the automotive that is that the twist beam. The study is concentrated on the multicriteria style of the automotive twist beam undergoing linear elastic deformation (Hooke's law). Indeed, for the look of this automotive half, there are some criteria to be thought-about because the rigidity (stiffness) and also the resistance to fatigue. Those 2 criteria are notable to be conflicting, therefore, our aim is to spot the Vilfredo Pareto front of this downside. To do this, we tend to used a standard Boundary Intersection (NBI) rule coupling with a radial basis operate (RBF) metamodel so as to scale back the high calculation time required for finding the multicriteria style downside. Otherwise, we tend to used the morpheme deformation (FFD) technique for the generation of the 3D shapes of the automotive half studied throughout the optimisation method. & 2016 Society of CAD/CAM Engineers. publication Services by Elsevier. this is often AN open access article beneath the CC BY-NC-ND license. within the automotive trade, and significantly, within the form style optimisation field, the foremost of issues faced are multicriteria ones. Indeed, a way to resolve these issues is to spot the Vilfredo Pareto front. To do this, there ar usually 2 problems to confront, the primary one is the way to scale back the process time needed by the standard ways wont to solve this type of optimisation downside, and also the other is however will we tend to generate the 3D shapes of the automotive half studied within the optimisation method. to beat the primary issue, it's necessary to couple ways for capturing the Vilfredo Pareto front with metamodels geared toward low-cost costs' evaluations. For the second issue, there are many versions of FFD technique wont to do that [1–3]. The Twist beam suspension (Fig. 1) is wide used as rear wheel suspension systems for front wheel driven traveller vehicles, it's composed of many parts like swing or trailing arms, bushings and also the twist beam that is that the object of our study. For our work, we tend to specialise in optimizing the form of a twist beam undergoing linear elastic deformation (Hooke's law) [4–6] to boost sure mechanical criteria like the rigidity and also the resistance to fatigue of this automotive half (Fig. 1). Firstly, for the identification of the Vilfredo Pareto front with an inexpensive calculation time, we tend to use the (NBI RBF) rule designed employing a coupling between the NBI methodology [7–10] and also the RBF metamodel [11– 15], the thought is to steer optimisation with the metamodel and solely do the precise evaluations of the metamodel obtained solutions [16–20]. Secondly, for the generation of 3D shapes throughout the optimisation method, we tend to use a developed version of the morpheme deformation technique exploitation radial basis functions (FFD RBF) [21–23].

Mr. Mario Eudardo city Martins et al "Formula SAE chassis design to improve suspension tuning" In several vehicle motorsport classes, the one in all the foremost vital factors that lead a team to the ending is that the suspension setup. Parameters like roll stiffness and camber dynamic square measure essential to the vehicle behavior throughout a driving state of affairs. To handle these variables, options like suspension arduous points arrangement, pivot points position and spring stiffness is settled. but a setup solely can perform a fascinating result if the chosen configuration doesn't amendment. Ideally, to form it doable, each element that holds suspension hundreds (suspension members, mounting plates and chassis) would need to be infinitely rigid. even if it's not doable, the prevailing deformation is sufficiently little to be negligible in comparison with suspension displacement. so as to achieve this target, this paper introduce a spring modeling and a Finite component multibody modelling method of a Formula SAE prototype's suspension and chassis. These models permits the investigation of chassis physical property result on suspension's operation properties. moreover, the info obtained square measure essential to line the chassis torsional stiffness target and therefore the final suspension's pick-up points geometries, avoiding Associate in Nursing outsized style. To validate the model a bench take a look at was performed to get a correlation between the important case and Finite component model, that reached a worth of ninety eight,2% and allowed the removal of excessive torsional stiffness and a mass reduction of 11th of September. Additionally, the study allowed to spot a vital stress purpose and a reinforcement was additional.

Mr. Hideki Sugiura et al "First order analysis of automotive suspension design" In suspension strategy planning stage , it's necessary to use performance prediction calculation for the alignment changes and compliance steer, with this being even a lot of vital within the influenced by the stiffness of every of its constituent members. To calculate the mechanical properties of a torsion beam suspension, finite part analysis and mechanical analysis are wont to date. for several style engineer , however, the planning-stage construction of a finite part model or a sophisticated mechanical analysis model that includes the elastic properties of its constituent members, and so playing calculations exploitation that model, needs an amazing quantity of your time and technical talent and is usually troublesome to accomplish. Thus, this analysis proposes initial Order Analysis as a CAE tool for style engineers which will be used with no special information or talent in modeling or analysis. we tend to additionally describe a style tool that was developed to calculate the properties of torsion beam suspension, and ensure the effectiveness of the tool exploitation examples and experimental verifications.

III. PROBLEM DEFINITION AND OBJECTIVE

Problem Statement

The contemporary open profile crossbeam is made of stamped sheet, and it has number child parts and higher weight. Basically it has lesser SRS ratio which is shaped typically in U or V form. This crossbeam is welded to trailing arm at its ends. It is obvious that the ends of cross beam should have greater section to improve the weld fatigue life at joinery. Since shape in plan view of conventional crossbeam remains usually uniform, it becomes necessary to add up reinforcements to support and improve the life requirement. The inherent section properties of open profile crossbeam is poor in bending stiffness and roll stiffness, causing high tyre wear. This makes necessary to take up support of additional Stabilizer bar and reinforcements to meet roll stiffness and durability requirements. Due to these constraints the open profile crossbeam becomes heavier and complex. Further effect of this drawback results in lower specific roll stiffness, high thermal stress, difficulty in meeting durability targets and sensitive to manufacturing process of twist beam assembly. The following is the baseline model of the open profile twist beam used in one of the entry level four wheeler cars. This model is taken as reference for the improvement in specific roll stiffness ratio and durability performance enhancement

Objectives

To explore weight optimization opportunity in rear twist beam weldment structure to improve the SRS ratio. To start any of the activity goal setting is must to have better clarity about the objective and aim. Below figure show the basic understanding about the target considered for the twist beam optimization on various front.

Below are the some main objectives

- Improvement in SRS ratio
- Weight reduction
- Cost optimization

Methodology

Close profile design activity start from the benchmarking wherein all the available benchmark vehicles study is being done from structural and performance point of view. Based on the benchmarking necessary design calculations have been done to finalize the twist beam section design. After above stages CAD concept has been prepared and it is been verified in CAE software In addition to this future scope have been also shown wherein physical validation stage is also shown.

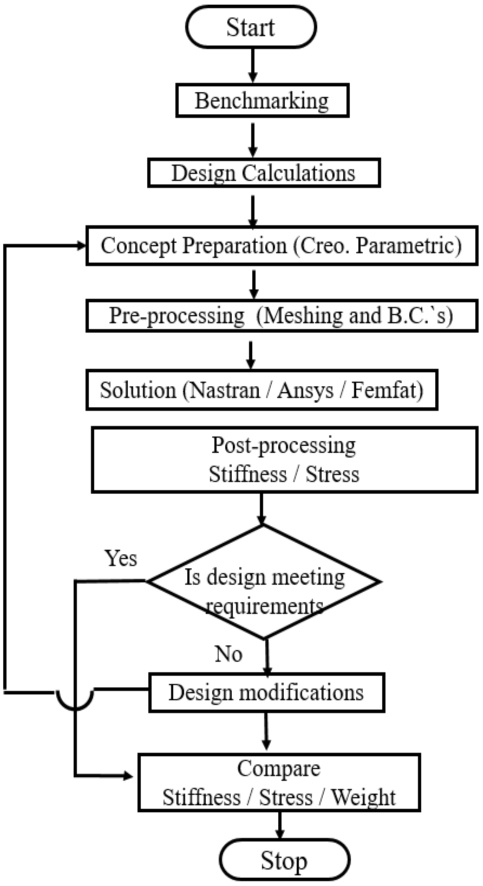


Fig 2. Methodology flow chart

IV. DESIGN

Open Profile twist beam:

In open profile rear twist beam design, the term open profile twist beam is defining the open tubular section of cross beam. Open profile twist beam design offers performance improvement like good torsional and substantial bending stiffness with the benefit of optimised part cost and process cost. In open profile twist beam design, child parts like wheel mounting bracket, two piece damper bracket, spring seat bottom and four reinforcements are welded together on trailing arm and cross beam. These child parts are welded together in close vicinity, as shown in below figures, resulting high residual and thermal stress in child parts and consequent structural failures.

Above figure show the close profile twist beam weldment structure in which the center part of the structure is called as open profile cross beam which is made by using sheet meatal as a raw material which is much simpler from manufacturing point of view then the close profile twist beam suspension. Below image shows the section view of cross beam wherein stab bar has been used to meet the roll stiffness target and associated parts has been added to meet weld fatigue life of twist beam. All the parts like cross beam inner reinforcement, box bracket, stabilizer bar are welded together very close to each other which is leading to the high thermal and residual stress in the weldment structure. Below figure show the open profile twist beam cross section.

As shown more number of child parts involved more welding which is leading to the generation of high thermal stress and distortion in weldment structure which may leads to the fatigue failure.

Advantages:

- Simple manufacturing process.
- Required standard sheet metal material.
- Required simple tooling

Disadvantages:

- Low specific roll stiffness ratio
- More number of child parts
- High heat affected zone leading to fatigue failure.
- Involved more welding.
- Higher weight.

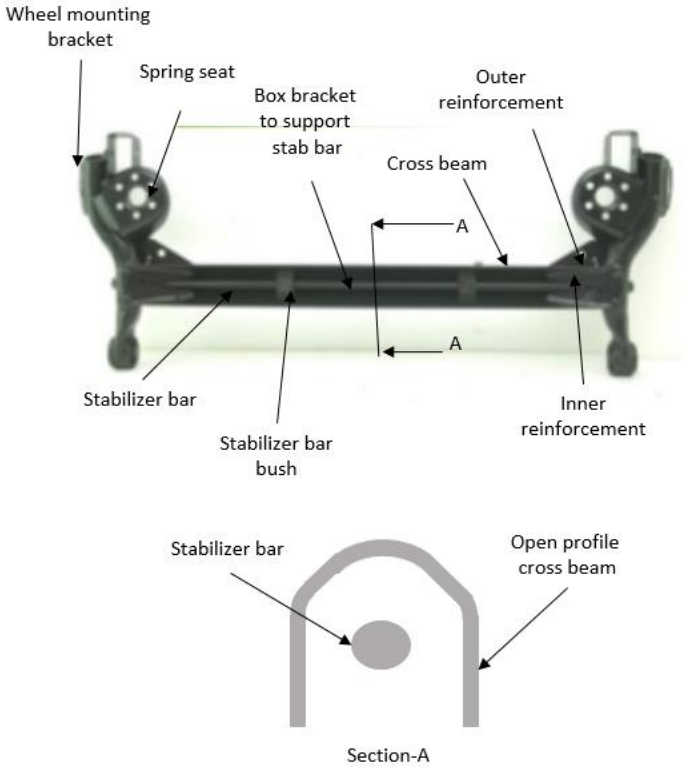


Fig 3. Open profile twist beam

Probable solution:

Based on the literature study and available benchmark data and advantages and disadvantages of both types of design. Open profile twist beam type suspension has more scope for weight and cost optimisation as compare to the close profile twist beam suspension system. Based on functional analysis it seems that cross beam is the main part which is providing the roll and bending stiffness to whole structure which are major parameters of any twist beam weldment structure. In open profile type of twist beam weldment structure this function is getting achieved by adding stabilizer bar with cross beam, which required lots of child parts to meet fatigue life requirement. Hence probable solution could be to meet all the dynamic and durability targets without stabilizer bar and its associate child parts which can served both the requirements Below fig 8 show the CAD concept of probable solution, wherein stabilizer bas has been eliminated and required function of stabilizer bar and it`s associated child parts has been met with the new cross beam and inner reinforcement design. This proposals helps to reduce child part count and welding, reduction in welding will help to reduce the HAZ and residual stress from rear twist beam weldment structure which was leading the weld fatigue related failures.

Close Profile twist beam:

In close profile rear twist beam design, the term close profile twist beam is defining the closed tubular section of cross beam. Close profile twist beam design offers performance improvement like better torsional and bending stiffness with the benefit of less weight and number of child parts. In this design. This type of suspension system has lots of advantages on weight optimisation front but it`s required huge process and raw material cost. Close profile twist beam could be made by two different manufacturing processes tube crash forming and tube hydroforming which required higher level of accuracy in tooling and number of tools also. For close profile twist beam high strength tube is required which is very costly as compare to the other materials used for twist beam manufacturing the close profile twist beam weldment structure in which the center part of the structure is called as tubular close profile cross beam which is made by using tube as a raw material. Below image shows the section view of cross beam.

Advantages:

- Less number of child parts.
- Reduced welding.
- Low heat affected zone due lesser welding.
- Light weight
- High specific roll stiffness ratio

Disadvantages:

- Limited raw material availability
- Required high strength tubes
- Required high level of tooling accuracy

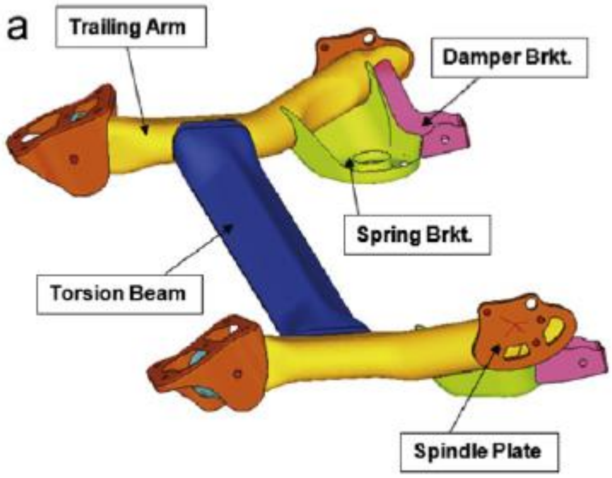


Fig 4. CAD Close profile twist beam structure

Design tunability:

Design tenability is an important aspect of any of the design, this design solution has large scope for the tenability by changing center section length in “Y” direction and other section parameters such as section height, section width and bulb radius through which roll stiffness requirement can be achieved. Also there is another location like transition area of cross beam wherein sections changes near to the cross beam and trailing arm joinery also has significant contribution in roll stiffness property of the beam. The main roll stiffness is govern by the cross beam section properties and effective length of cross beam section. The end profile can be used for tenability purpose. While meeting dynamic properties requirement it is important balance durability performance also. Below fig shows the various avenues for the roll stiffness tunability. The other opportunity to meet the roll stiffness and durability requirement in this type of design is to change cross beam section geometrical parameters like cross beam section height, section width and bulb radius basically through these parameters we can change the area enclosed by the section which driving the section roll properties. Below fig shows the scope for the tunability. Below fig shows the section selected in this optimized design proposal to meet roll stiffness and bending stiffness performance criteria. The other important aspect of this design is material selection appropriate thickness and raw material is very important from parent material and weld fatigue parent material fatigue life requirement point of view.

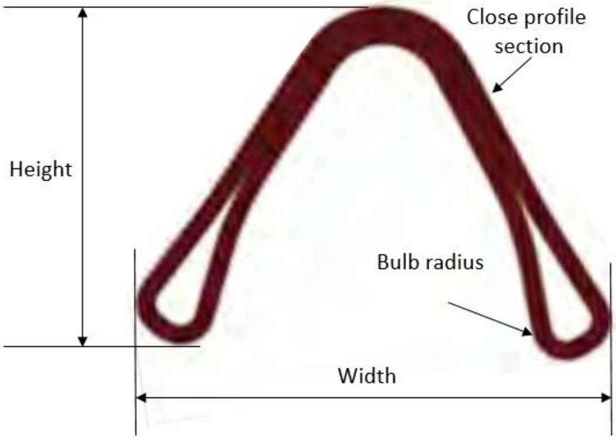


Fig 5. Close profile section

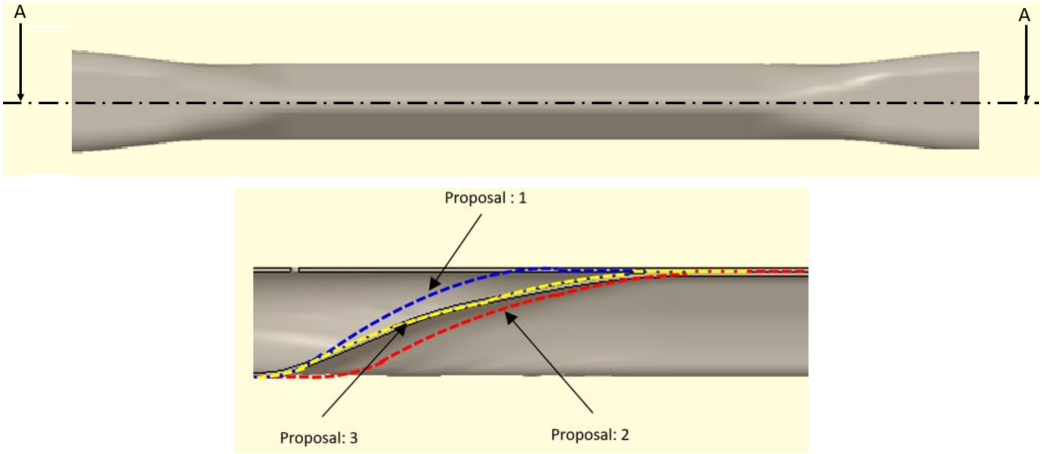


Fig 6. Transition area of close profile beam

Material Selection:-

Basic material properties of material used for twist beam.

Yield strength

a. Static and fatigue strength
b. Formability
c. Weldability
d. Coatability,
e. Fracture toughness at lower temperatures

Hydrogen embrittlement: The sensitivity regarding a hydrogen embrittlement play an important role in retaining of mechanical properties. Hydrogen embrittlement is the result of unintentional introduction of hydrogen into susceptible metals during forming or finishing operations and increases cracking in the material. In case of open profiles, micro alloyed high-strength low-alloy (HSLA)-steels in an Ultimate Tensile Strength (UTS)-range up to 550 MPa are currently getting used E46 steel.

Theoretical Calculations

$$\text{Specific roll stiffness ratio} = \frac{\text{Roll stiffness (k)}}{\text{Weight (w)}} \quad \text{-------------------Eq. 1}$$

Table 1: Weight calculations

Sr. No	Description	Conventional RTB Weight (kg)	New Design RTB Weight (kg)
1	Cross beam	8	8.2
2	Reinforcements	1.5	0
3	Stabilizer bar	3	0
4	Trailing arm	6	6
5	Wheel mounting bracket	2.5	2.5
6	Rubber bushes (Stab bar)	0.3	0
7	Pivot sleeve	0.2	0.2
Total		21.5	16.9
Total Weight Saving			**4.6**

Specific roll stiffness ratio calculations of conventional open profile twist beam:

Weight of the convention twist beam is given by 21.5 kg

Roll stiffness at wheel center of contemporary open profile twist beam is 420 N-m /deg.

Putting above given parameters in equation 1

$$\text{Specific roll stiffness ratio} = \frac{420}{21.5}$$

$$\boxed{\textbf{Specific roll stiffness ratio = 19.5}}$$

Specific roll stiffness ratio calculations of new design tubular close profile twist beam:

Le = Equivalent length of beam in Torsion

P beam = Perimeter curve length at middle of the beam thickness.

t = Thickness

J min = Polar moment of inertia

K total = Total roll stiffness

K beam eff = Beam roll stiffness

A = Enclosed area

G = Modulus of rigidity

Tp = RTB pivot track

Pw = Pivot to wheel center distance

Rf = Reduction factor due to cross beam location.

Kw = Roll stiffness at wheel center

Tw = Wheel track

K lf = Roll stiffness at beam location factor [3]

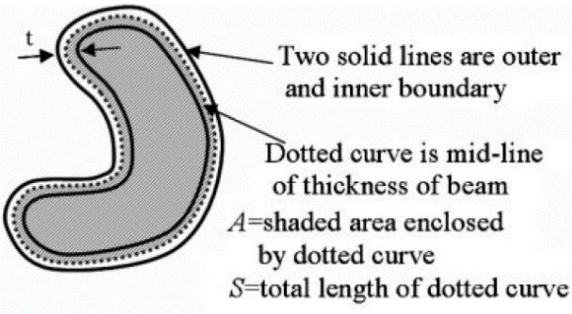


Fig 7. Area enclosed

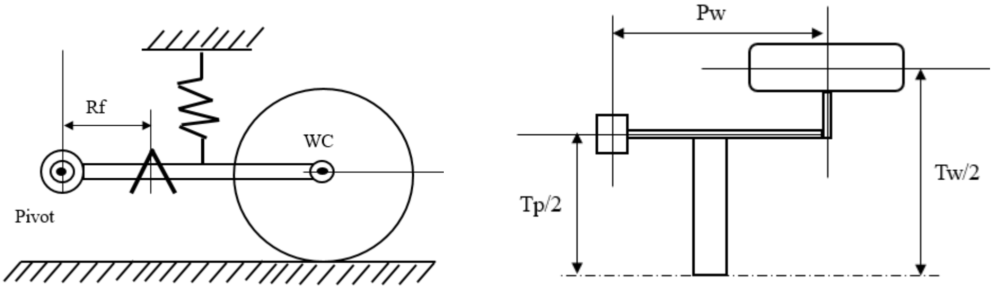


Fig 8. Twist beam model

Torsional Stiffness of cross beam [3]

$$K\ beam = \frac{G\ \ J\ min}{Le}$$

$$J\ min = \frac{4\ A^2\ t}{P\ close} \qquad [3]$$

$$K\ beam\ eff = \frac{G\ x\ Jmin}{Le}$$

$$Kw = \frac{\frac{1}{2}\ (K\ lf)\ (Tw)^2}{\sqrt{\left[\left(\frac{Tw-Tp}{2}\right)^2 + (Pw)^2\right] Pw}}$$

Putting all the values in above equation we get

Kw = 432 Nm/deg.

Weight of the convention twist beam is given by 16.9 kg

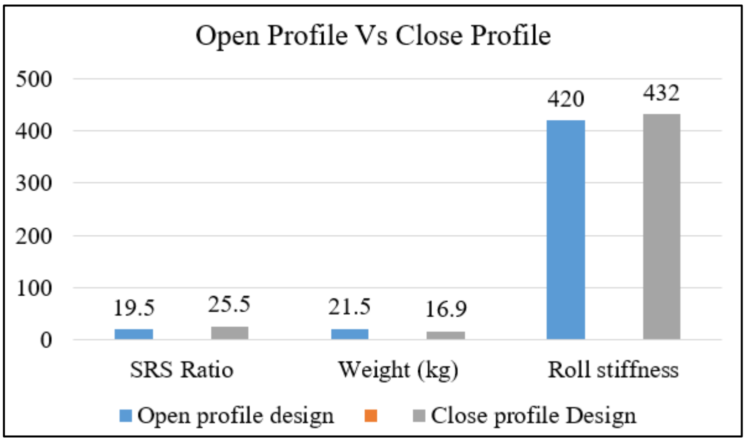
Roll stiffness at wheel center of contemporary open profile twist beam is 432 N-m /deg.

Putting above given parameters in equation 1

$$Specific\ roll\ stiffness\ ratio = \frac{432}{16.9}$$

Specific roll stiffness ratio of close profile tubular twist beam = 25.5

From above mathematical calculations it is observed that the specific roll stiffness ration of contemporary design is 19.5 and specific roll stiffness ration of new design is observed 25.5 which is improved form the baseline design, High specific roll stiffness ration indicates the level of design optimization against the target roll stiffness requirement which is being derived from the rear axle weight target of the subject vehicle.



Graph 1: Calculation comparison

Above graph shows the comparative results of open verses close profile twist beam design wherein all the significant parameters are compared. Close profile twist beam has shown significant improvement in all the above parameters like SRS ratio, weight, no of child parts and overall weld length.

V. FINITE ELEMENT ANALYSIS

The finite part technique (FEM) may be a numerical technique for locating approximate solutions to boundary worth issues for partial differential equations. FEA analysis is performed to estimate roll stiffness and the stress coming on the both contemporary open profile twit beam and new close profile design to figure out the level of improvement in the specific roll stiffness ratio.

Flow Chart:

As you innovate new, improved products, your design evolves through a large number of incremental changes. We need to be able to predict how these intended improvements influence real world performance, for better or for worse.

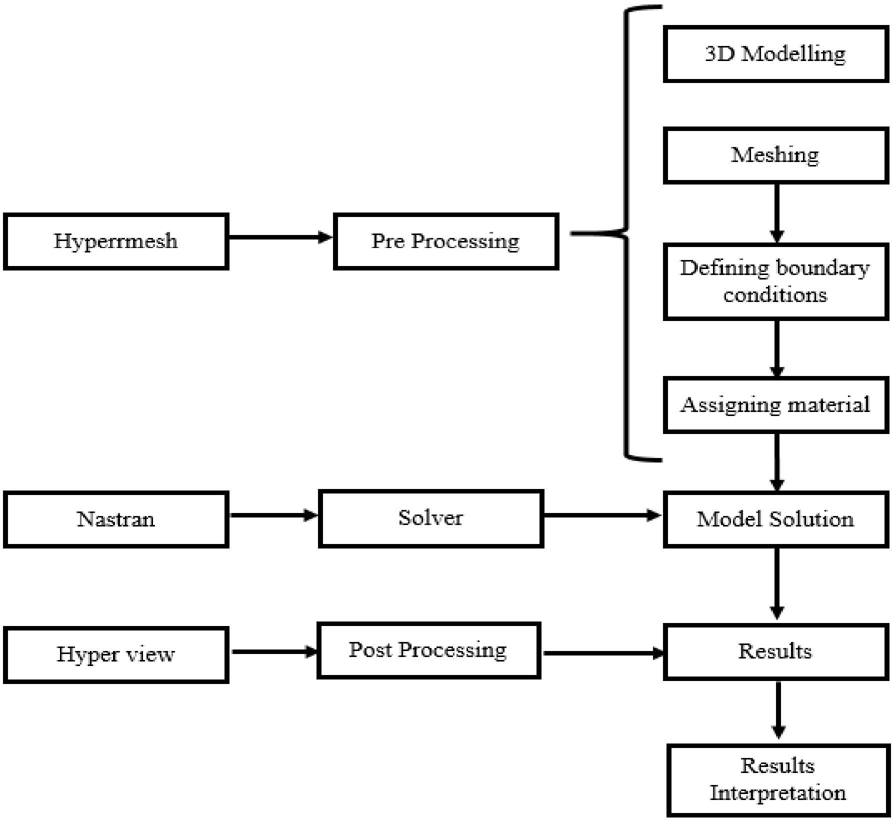


Fig 9. Flow chart of design verification and validation process

Computer aided engineering simulation allows engineers to see into the future, predicting the consequence of any design change on the real- world performance of their products. Deployed effectively, it can be used to improve your design through multiple iterations, providing data to guide the design process from its earliest stages, through to production and beyond. Above flow diagram elaborates the stapes to be followed during FEA analysis.

Load application for Analysis

Loading the structure can be done by various methods. One of the best method found is by applying loads at the face of the wheel mounting bracket. This gives more co-related results. Here in this simulation 1000 N load is being applied on wheel mounting bracket which need to be given equal and opposite for LH and RH ends. Loading for RH is downwards while the loading for LH is upwards as shown in below figure for the roll stiffness and stress estimation on the new and baseline design.

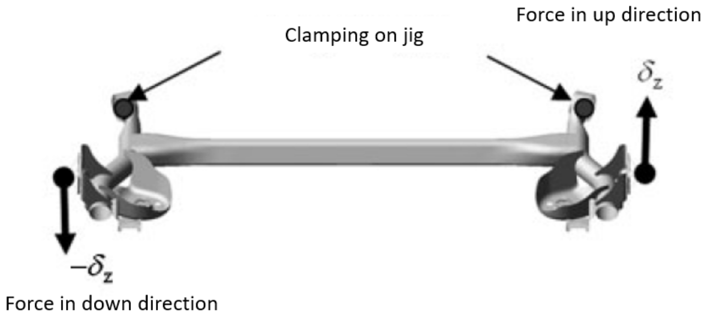


Fig 10. Load application direction

Stiffness Analysis

The simple phenomena of couple is used to evaluate roll stiffness. The figure below shows an idea about methodology. One end of RTB is loaded by LH force and other end by RH force. When two equal and opposite forces applied to a flex body, they cause a couple. The couple causes assembly to twist as in the vehicle roll condition. The cad assembly always consists of imperfections. Imperfections lead to wrong results. We need to resolve the imperfections before analysis. After developing a good CAD assembly, it can be used further to apply welds, loads, meshing as explained is further topics. The twist angle can be simulated in Nastran. This angle can be calculated by measuring the deflection 'Z' at ends as shown in fig below. Further applying basic physics roll stiffness of RTB can be evaluated as per below formula's explained further. This process is being followed in CAE software for the roll stiffness verification of both the baseline open profile twist beam design as well as close profile twist beam also

$$Roll\ Stiffness = \frac{\text{Couple (Nm)}}{Twist\ Angle\ \text{(deg)}}$$

$$Roll\ Stiffness = \frac{\text{F x T (Nm)}}{\phi\ \text{(deg)}}$$

F : force applied on both ends.
Z: deflection at RTB ends
T: RTB track
x: half the RTB track
ϕ : Twist angle

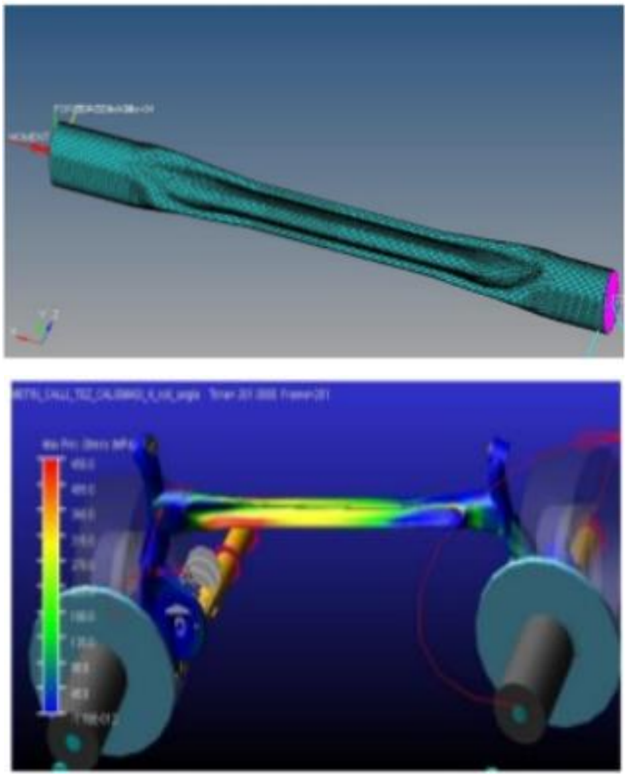


Fig 11. Meshed cross beam model & Load application direction

Stress Analysis

Baseline open profile twist beam

The maximum equivalent stress observed during the severe roll fatigue block cycle run in the twist beam is 425 MPa. The yield strength of the material is 460 MPa. According to results, the von-Mises stress 425 MPa is lower than yield strength of the material. The factor of safety of the baseline open profile twist beam is 1.07. Above stress plot of baseline twist beam shows the factor of safety more than 1 and some portion having the factor of safety more than 10. This indicates that baseline model is safe under the given working conditions.

Risk factor in open profile twist beam:

Based on the stress pattern observed in the above analysis the stress are well within the limit but it is at the edge of the twist beam and inner reinforcement which may goes up significantly higher in rough surface finish on part edge which is highly dependent up on the manufacturing process capabilities which may reduce to fatigue life of part.

New close profile twit beam design

Initial design proposal stress were above the material yield limit which required further fine-tuning in design to bring it below the material yield limit considerably. In final design iteration the stress are observed within the acceptable limit at twist beam transition zone. In any type of twist beam the transition area were section changes which is approximately ~200 to 350 mm away from the cross beam trailing arm joinery is a high stress zone of twist beam. The maximum equivalent stress observed during the severe roll fatigue block cycle run in the twist beam is 361 MPa. The yield strength of the material is 460 MPa. According to results, the von-Mises stress 361 MPa is lower than yield strength of the material. The factor of safety of the baseline open profile twist beam is 1.21. Factor of Safety of modified design of twist beam shows the factor of safety more than 1.2 which showing the improvement in the durability performance as compare to baseline design and at some portion having the factor of safety more than 15. This indicates that new design is safe under the given working conditions. As this is the tubular section there will not be any risk related to edge condition and sensitivity of the same towards durability performance.

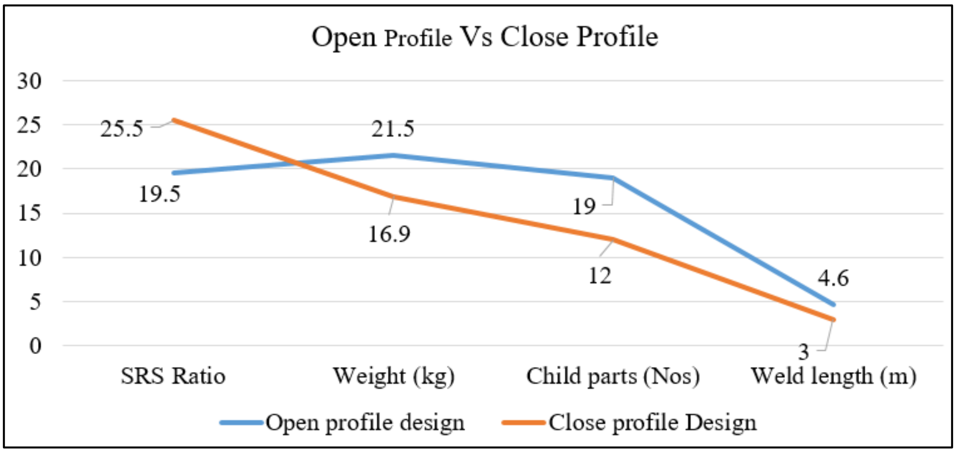
VI. RESULTS

In above study new close profile tubular twist beam design is being done and it is been compared with baseline design to see the improvement in new design. Below table shows the comparative results of both the design to understand the error identified in theoretical analysis against the software simulation and also percentage improvement achieved in new design is also tabulated. New design has shown significant improvement in all the below parameters.

Table 2: Result comparison

Method	Design	Description				
		SRS Ratio	Roll stiffness (N-m/deg)	Weight (kg)	Child parts (Nos)	Weld length (m)
Theoretical Calculations	Open profile Design	19.5	420	21.5	19	4.6
Software Simulations		18.8	405	21.5	19	4.6
Error %		3.7	3.7	0	0	0
Theoretical Calculations	Close profile Design	25.6	432	16.9	12	3
Software Simulations		24.8	419	16.9	12	3
Error %		3.1	3.1	0	0	0
Improvement %	Close profile vs open profile Design (software simulation)	31.6	3.5	21.4	36.8	34.8

Below graph shows the comparative results of open verses close profile twist beam design wherein all the significant parameters are compared. Close profile twist beam has shown significant improvement in all the above parameters like SRS ratio, weight, no of child parts and overall weld length



Graph 2: Result comparison

VII. CONCLUSION

Existing and optimized model of twist beam has been evaluated for roll stiffness and stress under given boundary conditions to determine the specific roll stiffness ratio by carrying out static structural analysis in Nastran workbench. As deflection and stress of optimized model is within the range. Thus, the modified design is safe. Weight of the final optimized model is 16 kg. The percentage reduction in mass and material cost is observed 17.5% and improvement in SRS ratio from 19.5 to 25.5 by keeping factor of safety for optimized design within permissible limits. Thus the objective of improvement in SRS ratio by improvement in roll stiffness and reduction in weight and vis a vis cost reduction has been achieved. Improvement in SRS ratio is a very effective way to improve a vehicle's efficiency and reduction in carbon emissions. In addition this innovative arrangement renders the thermal and residual stress by better distribution of welding across the assembly.

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