

Design & Analysis of Rocker Arm Suspension System Used in FSAE

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ABSTRACT: This paper converse information about the study of design of rocker arm suspension system used in FSAE. Formula racing concept in the university campus is to make FSAE racing have better ride comfort, handling and stability. Rules studied by FSAE are followed which are mainly focus on drivers safety. After selection of type of suspension system, the important parameter such as rocker arm, pushrod and spring. Softwares like CATIA R5V21 and ANSYS are used to obtain 3D models and analyse the model respectively. Dynamic analysis is performed on ADAMS. The main parameters and the orientation structure of the front and rear suspension were preliminarily designed. The wheels alignment parameters were selected with all kinds of stiffness, damping coefficient, followed by cross arm length calculation. According to the design parameters, suitable rim and shock absorber were chosen to determine the structure of the suspension's main components. Also,, the front and rear suspension models were set up and analysis of static stress on the main components of FSAE racing using the simulation module was performed to form the car suspension system so that it meets the design requirements of the FSAE regulations.

KEYWORDS:Rocker arm suspension attachment, springs, productivity, calculations etc.

I. INTRODUCTION

Suspension system plays vital role in the performance of car. Primary function of suspension system is ensuring the comfort of passengers, keeping the contact between tyre and road surface and damping the force acting on vehicle. Rocker arm suspension system provide good contact patch which gives good acceleration as there is provision to adjust the spring stiffness This system used rocker arm, push rod and spring which makes the system light in weight than conventional suspension system. There by it also helps to reduce the weight of vehicle. As it requires less space, it helps to reduce track width of vehicle. Simultaneously it offers less resistant to air which influences the aerodynamic of car. Use of bell crank improves the force transmissibility of system. The spring should be stiff enough to withstand against the forces acting on vehicle and weight of vehicle including frame, engine and body. This depends on the accuracy in design and manufacturing of system which helps to improve performance of vehicle. Suspension is a very important component of any car as which keep the tyre in contact with the road while distributing forces acting on the tyres. The type of suspension used decides how these forces are transferred from the tyres to the chassis.

II. RELATED WORK

In automobile industry it is essential to produce the Compact and reliable Suspension system in order to increase the vehicle performance. Also, lot of forces during cornering, acceleration and bump conditions are also applied directly during dynamic condition. This article shows the design of FSAE suspension. [1] We presented in detail design procedure of the front double A-arm push rod suspension system for a formula student race car. The type of suspension systems used generally are calculated. The models of the components in the suspension system are made using Catia V5R21 and the Finite element analysis of the components is done using ANSYS Workbench. Both kinematic and dynamic analysis of the designed suspension system is performed. The results of vibration or ride analysis and roll steer analysis are also presented for the designed suspension system. The method for spring design is clear. This work describes the method for designing and analysing the suspension system for racing cars. [2] Our main aim is to design and analyse the suspension system for f1 student vehicle. Special emphasis is laid on achieving accurate results by using software based analysis. The results of the simulation in ADAMS are also shown for better understanding of the system. [3] FSAE race car is taken as the research object, dynamic performance of the suspension system is studied. 3D model of the whole vehicle suspension system is built by using 3Ddimensional modelling software, and the kinematics simulation is carried out. On the basis of this, ADAMS software is used for dynamic simulation, the changes of kingpin inclination angle, kingpin caster angle, camber angle, front wheel toe angle and ground point lateral slip amount of

front wheel with wheel beat is analysed, and the outer wheel angle has been optimized and designed. [4] Forces are generated at the tire contact patch during various car and transferred to the chassis through the suspension links. Forces on every link is important to design the suspension system are calculated from wheel to chassis by suspension linkage. These forces have been calculated for all the links of a double wishbone suspension geometry. [5]

III. DESIGN PROCEDURE OF FSAE SUSPENSION

Roll centre height was decide 58.3mm from the ground. Generally in a race car have negative camber in order to have lateral force and toe out due to respite during turning. From the survey of commercially available knuckles, at rear zero. King Pin inclination and vertical distance between mounting points of lower and upper. H-arms of 212mm along with a track width of 1084mm was chosen for the first iteration. The coordinate system was followed throughout a procedure.

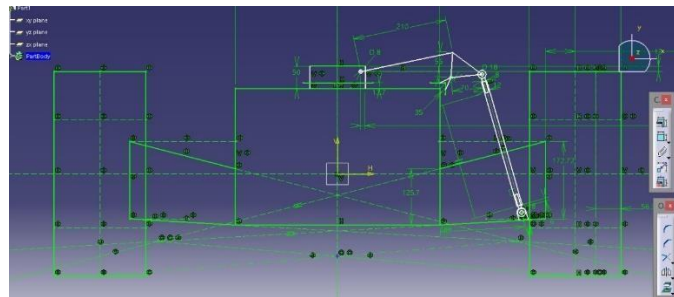


Fig.1 CAD model Suspension design

The mounting points of the H-arms on chassis were labelled as keeping the length track width fixed, lengths of H-arm, and were height from ground varied and graphs were plotted for variations in the wheel alignment with the wheel travel, using the kinematic analysis carried out in section. The geometry with minimum variation in wheel alignment with wheel travel was finalized. The next decision to be made was the length and height of mounting points and dimensions of pushrod and bell crank. One end of the pushrod was mounted on the lower H-arm closer to knuckle. Due to the space constraints on the chassis, the maximum length of spring was fixed and the maximum compression of the spring it was decided to be 25.4mm. Thus the final problem was the maximum and minimum angles for 25.4mm movement of the spring. The maximum and minimum angles of pushrod is jounce for 25.4mm and for rebound 25.4mm. Thus, it was a problem of four bar mechanism in which the length of central link was fixed and the range of angles for input link and output link known. The problem was solved by geometrical constructions to find the point on chassis as the mounting point of push rod on bell crank. Thus the shape of bell crank was decided. After choosing the geometry, the finite element analysis of each link and the performance of suspension (ride, roll and pitch analysis) were carried out using dynamic analysis demonstrated. An iterative procedure was carried out until satisfactory kinematic and dynamic results were find on Adams.

Bell Crank Design: Using laser cut, bell crank design is quite simple and easy to manufacture. In bell crank design firstly geometry diagram is started by which the angle between pushrod and shocks can be checked. The angle between pushrod and shocks is from $80^{\circ} - 120^{\circ}$ for better load transfer.

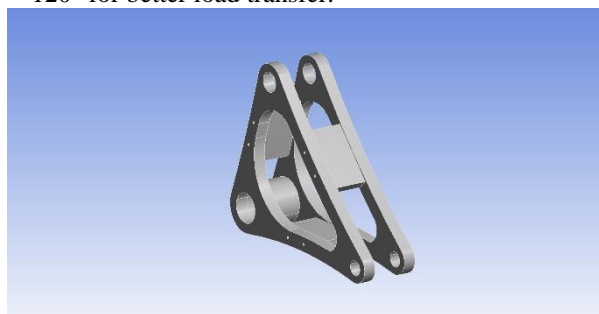


Fig. 2 Design of Bell Crank

Which reduce weight in bell crank; bell crank is first drawn by checking the angles between pushrod and shocks and geometry. After some solutions final bell crank design was finalized and completed its manufacturing process too.

Shocks Selection: The shocks selection is done on the basis of the design requirement and the analysis and on the

Performance, cost and on the market availability. By comparing all the parameters, DNM BURNER RCP 2 was finalized.



IV. STATIC AND DYNAMIC ANALYSIS

The static and dynamic analysis was used to obtain the spring stiffness and to the maximum loads on each component respectively. F_x , F_y , F_z were taken as the lateral, vertical and longitudinal force acting on the wheel respectively. At static condition, the vertical force acting on the wheel would be the total weight transfer on front wheel and the lateral and longitudinal forces acting on the wheel would be zero. From the force and moment balance equations about joints, forces on corresponding linkages were count up.

Simulation Results

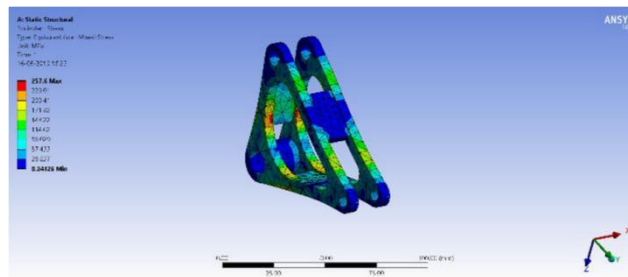


Fig. 4 Ansys of bell crank

V. CALCULATION

SUSPENSION LOAD DISTRIBUTION:

LATERAL:

Lateral acceleration (g)*Weight (lb)*C.G Height/Track width

LONGITUDINAL

Acceleration (g) (Vehicle Weight (lb)*cg Height (in)/Wheelbase)

Assumed Vehicle weight (without driver) = **190kg**

Drivers weight = **60kg**

Total weight of vehicle with driver = **250kg**

Assuming **40:60** weight distribution

Weight at front = **100kg**

Therefore, weight on each wheel = $100/2 = 50\text{kg}$

Weight at rear = **150kg**

Weight on each wheel = $150/2 = 75\text{kg}$

Track width [Front] = **1182mm**
 Track width [Rear] = **1064mm**
 Wheelbase = **1545mm**

Load Calculations

Longitudinal Forces during Braking: While Braking, the weight of the rear side tends to come in the front side of the vehicle so there is a load transfer that is taking place from rear to front. It internally affects the knuckle as these forces act on the A-arm mounting points through the A-arms.

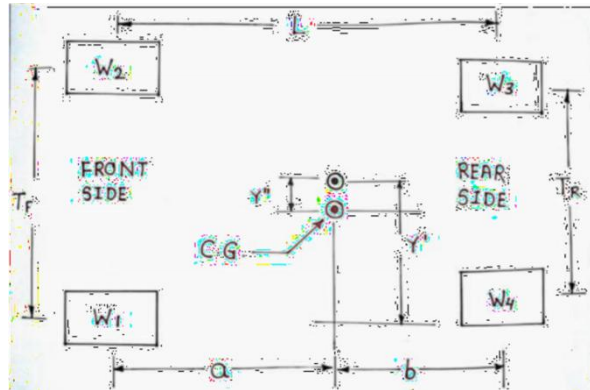


Fig. Measurement of Vehicle

Load Calculations:

Longitudinal Forces during Braking:

Considering Max. Acceleration of $1g = 9.81 \text{ m/s}^2$

Force at the front side = mass at the rear side of the vehicle \times acceleration

Let the mass at the rear side of the vehicle be 0.6 times the total weight

Mass at rear side of the vehicle = $0.6 \times 250 = 150 \text{ kg}$

Force = 150×9.81

Force = 1471.5 N

Now force on 1 wheel = $1471.5/2 = 735.35 \text{ N}$

Longitudinal Force = 735.35 N

Lateral Forces: Lateral forces are because of two reasons –centrifugal force and lateral load transfer from outside to inside while turning. The centrifugal force is considered as follows.

Let the vehicle take a turn of 7m turning radius and at a speed of $35 \text{ kmph} = 9.72 \text{ m/s}$. $r = \text{turning radius} = 7 \text{ m}$

$1 \text{ km} = 1000 \text{ m}$; $1 \text{ hr.} = 3600 \text{ sec.}$

$$1 \text{ km/hr} = \frac{1000}{3600} \text{ m/sec} = \frac{5}{18} \text{ m/sec}$$

To convert km/hr into m/sec, multiply the number by 5 and then divide it by 18.

$$\text{Centrifugal Force} = \frac{m \times v^2}{r} = \frac{0.4 \times 300 \times 8.3333^2}{6} = 1349.69 \text{ N}$$

Now consider if all the weight at the front side comes on the wheel assembly the force will be Force due to lateral load transfer = $0.4 \times 250 \times 9.81 = 981 \text{ N}$

Vertical Force at Bump: The vertical load transfer occurs at bump and as per load theories 3g of weight applies on vehicle at the time of bump.

Vertical load transfer on each wheel (Front)= $490.5 \times 3 = 1471.5\text{N}$

Vertical load transfer on each wheel (Rear)= $735.75 \times 3 = 2207.25\text{N}$

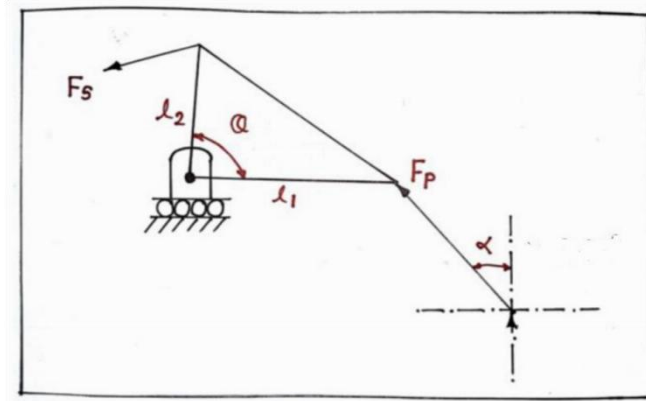


Fig. Rear Suspension Geometry Free Body Dia.

Suspension Calculations:

Rear Suspension

(MR)= Wheel Travel /Spring travel

Motion ratio[Front] at jounce = $30/21 = 1.42$

Motion ratio[Front] at Rebound = $30/18 = 1.6$

Motion ratio [MR][Front] = $1.42 + 1.6 / 2 = 1.5$

$\alpha = 19.20$ $\beta = 90$ Therefore

$$F_p = 2207.25 \cos \alpha$$

$$= 2207.25 \cos(19.20)$$

$F_p = 2085.10\text{N}$

$$\text{BMR} = L1/L2 \sin \theta$$

$$= 56/70 \sin(90)$$

BMR = 0.8

Now, Considering ride frequency of front as **2 Hz**

Therefore, **Fr = 2Hz**

$$K_s = 4 \times \pi^2 \times Fr^2 \times M_{sm} \times MR^2 \quad [20]$$

$$K_s(\text{Front}) = 4 \times \pi^2 \times (2)^2 \times 165 \times (1.5)^2$$

$K_s = 58625.46\text{N/m}$

Therefore, selecting stiffness of front as **58635.45N/m** or

58.6N/mm

$$K_w [\text{Front}] = (K_s)/MR^2 [21] = 58/(1.5)^2$$

$$K_w[\text{front}] = 26.04 \text{ N/mm}$$

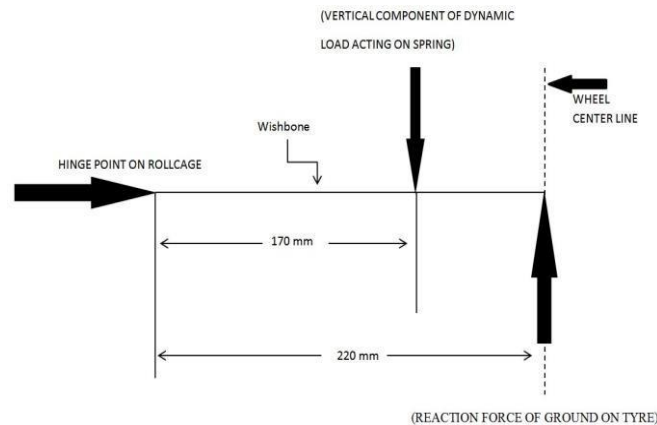


Fig. Forces on wishbone

VI.METHODOLOGY

- Firstly, we started the work of this project with literature survey and gathered many research papers which are important to this topic.
- Based on mechanical properties we selected the suitable material
- We did calculations and 3D model design.
- After that we selected the materials for the components based on mechanical properties.
- Result may calculated based on testing.
- The components will be manufactured and then assembled together.
- The testing will be carried out and then result and conclusion of topic will be drawn.

VII.CONCLUSION

After we selected the materials for the components based on mechanical properties. We have done the calculations for the components. After doing the calculations of components, the 3D model is done with the help of CATIA software. The components will be manufactured and then assembled together. The testing will be carried out and then results and conclusion will be drawn.

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