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Structural Analysis on the Effect of Eccentric Loading on the Automobile Chassis for Optimum Design

Mr.Akkipalli Pavan Kumar[1], Dr. G.Maruthi Prasad Yadav[1], Mr. V.Chengal Reddy[1], Mrs.T.Nishkala[1].

[1]Dept. of Mechanical Engg., Chadalawada Ramanamma Engineering College, Tirupati, Andhra Pradesh 517506, India.

Abstract : Along with clearance, length of overhangs affects the approach and departure angles, which measure the vehicle's ability to overcome steep obstacles and rough terrain. The longer the overhang, the smaller is the approach/departure angle, and thus lesser the car's ability to climb or descend steep ramps without damaging the bumpers. Therefore these overhangs are lifted up to avoid damage. But the front overhang is having limitation due to accommodation of engine. Whereas, the rear overhang can be raised up for the convenience, to improve vehicle safety. The provision of rear overhang height leads to eccentric loading action on the frame due to front impact. Thus in this work an attempt is proposing to study the behavior of chassis frame under action of front impact by varying the height of rear overhang.

Also it can be seen that the front impact may not act all the time through the CG of the chassis frame, it is further proposing to study the chassis frame behavior considering the eccentric load action from the front of the vehicle.

The model of Chassis frame is made using Catia V5, followed by analysis using Ansys 15.0 to study the stress, deformation and safety factors development. The analysis is repeated by considering different rear overhang heights.

Also the analysis is repeated by considering the eccentric loading condition and further a modification is suggested to design of chassis frame for improving the load bearing capacity based on the obtained results. And the analysis is done on suggested modified chassis to compare the results with existing model.

***IndexTerms* - Chassis, Eccentric loading, Structural analysis.**

I. INTRODUCTION

Automotive chassis is 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 helps keep an automobile rigid, stiff and unbending

II. OBJECTIVE

In this present work, an attempt is made to study the stability of the chassis under the action of eccentric loading condition due to front impact and also by varying the height of rear overhang. A modification is proposed by providing additional supporting members (angle members) connecting the front cross member to side members for the improvement of impact load distribution and thereby to find the optimum design of the chassis frame.

The model of the chassis frame is done using Catia V5 and analysed the effect of the eccentric loading condition and height of rear overhang for existing and proposed modified chassis frame model by carrying structural analysis using Ansys 15.0.

III. STEP BY STEP MODELING PROCEDURE OF CHASSIS FRAME

The step by step procedure followed in creating the model of Automobile Chassis Frame is shown in the following figures.

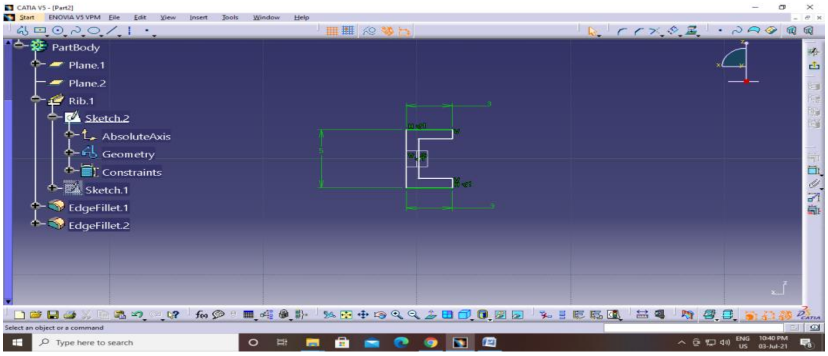

Fig 3.1 Sketch of cross section of side member of Chassis frame in Catia V5

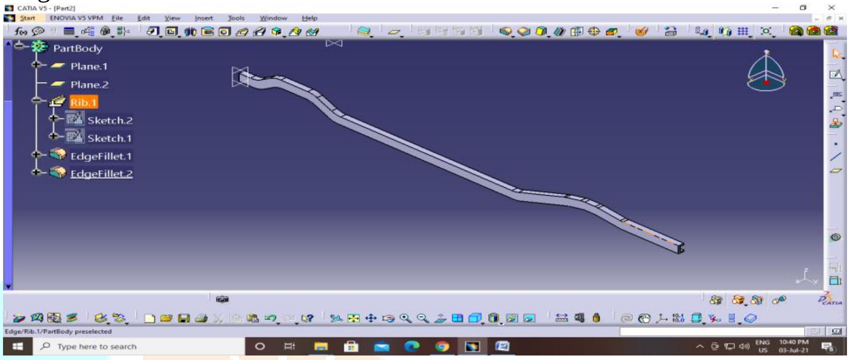

Fig 3.2 Created side member of Chassis frame in Catia V5

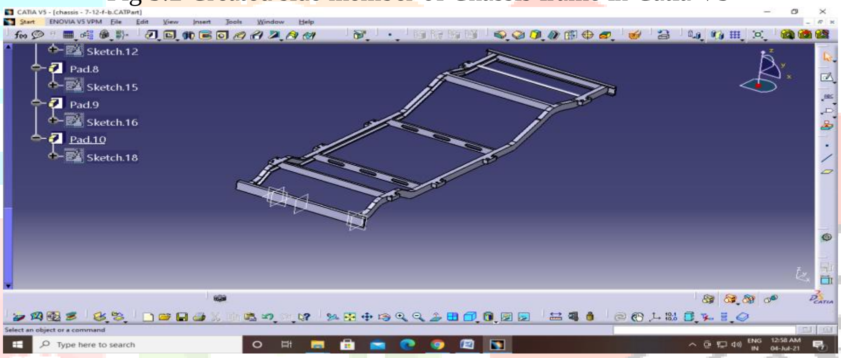

Fig 3.3 Creation of chassis frame in Catia V5

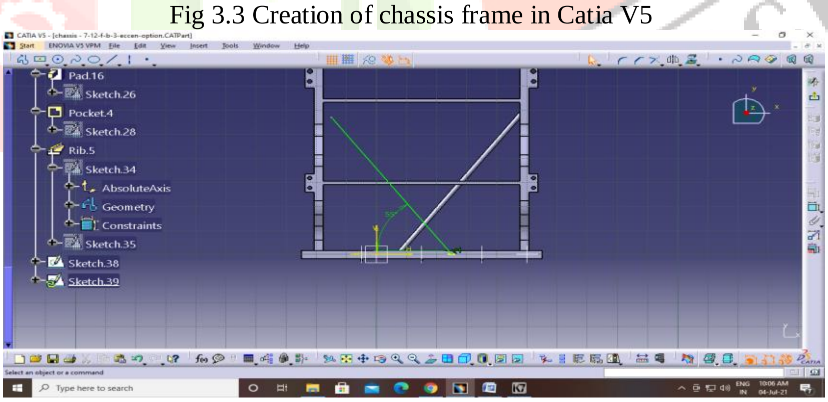

Fig 3.4 Creating angle members for suggested modification to chassis frame in Catia V5

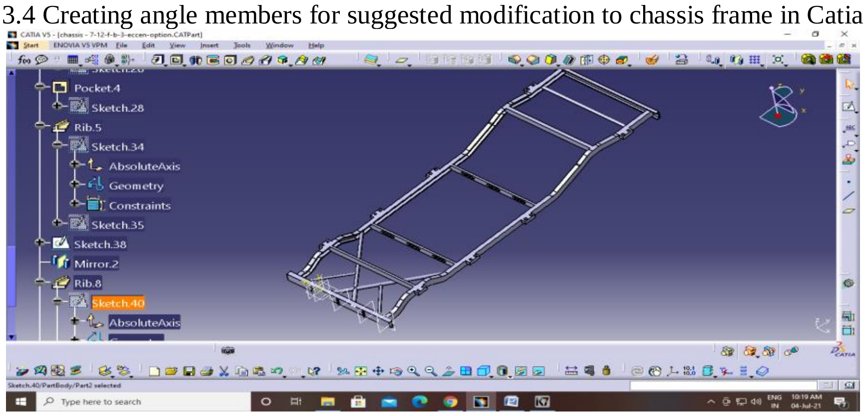

Fig 3.5 Creation of angle members for suggested modification to chassis frame in Catia V5

Similar procedure is applied to create the following models of automobile chassis frame.
Let S is the ratio of front to rear overhangs height
Chassis Frame Model-1: S-1.1,
Chassis Frame Model-2: S-1.4,
Chassis Frame Model-3: S-1.7,
Chassis Frame Model-4: S-2,
Chassis Frame Model-5: S-2.3,
Also the following cases are considered for analysis
Eccentric Loading case-1: Load applied for 50% of the span of front cross member of Chassis Frame
Eccentric Loading case-2: Load applied for 25% of the front cross member of Chassis Frame from the middle
Eccentric Loading case-3: Load applied for 25% of the front cross member of Chassis Frame from the end

IV. Step by Step Analysis Procedure (Automobile Chassis Model-1)

Step 1: At first the ansys 15.0, structural analysis is to be loaded. Then the material required is selected as shown in fig 4.1.

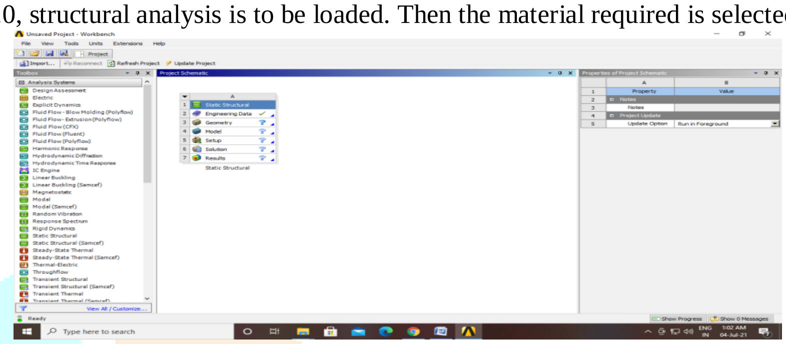

Fig 4.1 Structural analysis and selection of material in Ansys 15.0

Step 2: The Catia model is to be imported in igs format as shown in fig 4.2

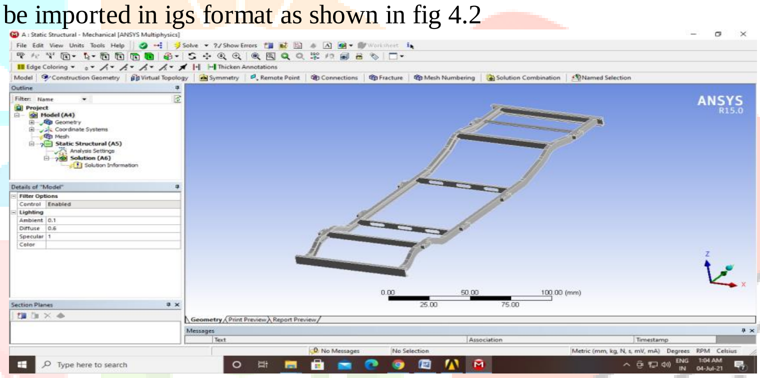

Fig 4.2 The catia model of Chassis frame is imported to Ansys 15.0

Step 3: The model is divided in finite parts and meshed model is as shown in fig 4.3

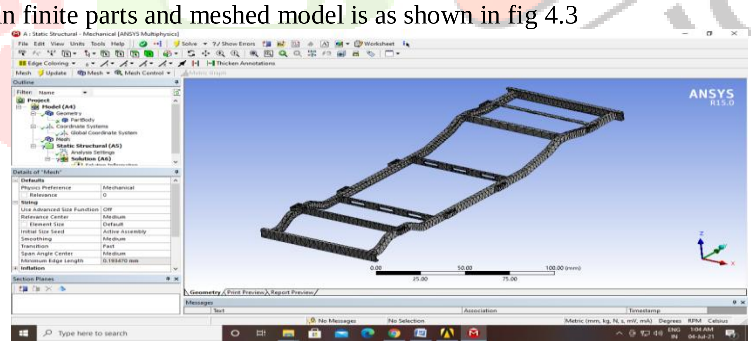

Fig 4.3 Meshed model of Chassis frame in Ansys 15.0

Step 4: The fixed constraints are applied as shown in fig 4.4.

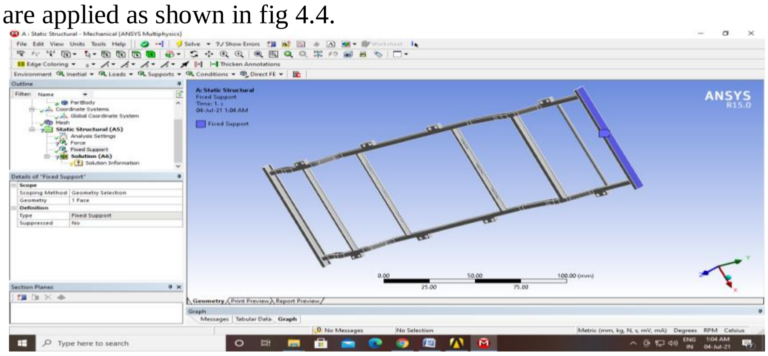

Fig 4.4 Applying fixed constraints in Ansys 15.0

Step 5: The load is applied to the model as shown in fig 4.5

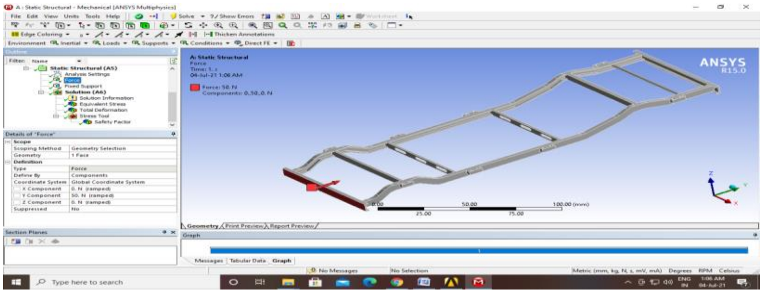

Fig 4.5 Applying load to the model.

Step 6: Then to solve the problem using solver option.

Similar procedure is applied to all the cases and results are discussed in the next section

V. Results and Discussions

5.1 Ansys Results of Chassis Frame Model-1

The fig 5.1 shows the equivalent stress distribution in the chassis frame model-1 under impact from the front. The resulting color image shows that the front and rear overhang are under higher stress intensity development compared to the remaining part of the chassis frame. Also it can be observed that the side members took the major contribution in withstanding the load than the middle cross members. Also the front cross members are under higher stress development. The maximum stress developed in the chassis frame is found to be 116.06MPa, which develops at front overhang, where side starts rising up.

The fig 5.2 shows the deformation developed in the chassis frame model-1. The resulting color image shows that deformation decreases from front to the rear of the chassis frame. The maximum deformation developed in this model-1 is found to be 0.732mm, which is developed in the front cross member of the frame. The frame is found top be under bending form of deformation that leads to bending action of the frame towards the ground about the rear end. Thus the frame is under dipping action which can be reduced by providing suitable suspension system. The bending action is due to the shape of the frame, having front and rear overhangs at higher levels than that of the middle portion of the frame. Especially it can be observed that the rear overhang is under safe region under the considered impact load from the front.

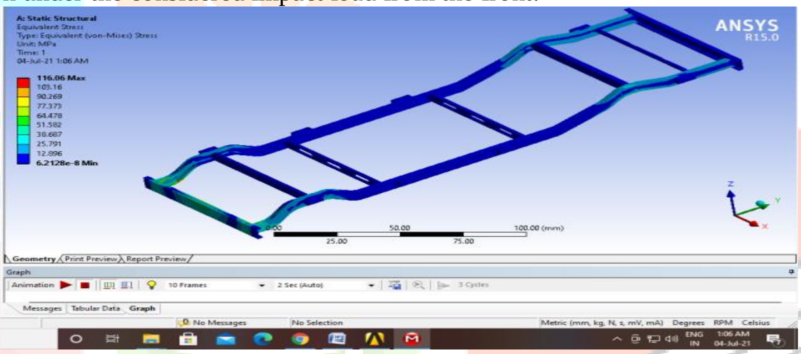

Fig 5.1 Equivalent von-mises stress distribution in the chassis frame model-1

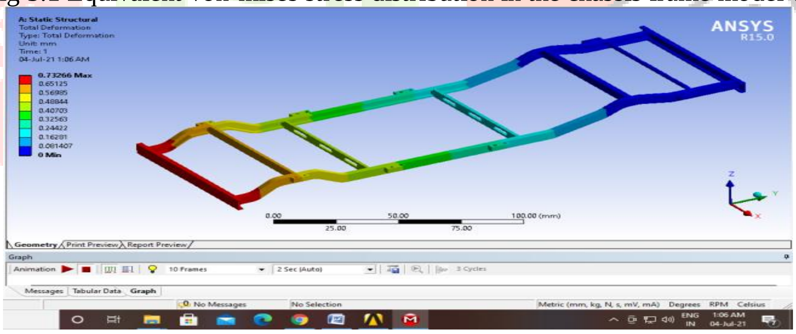

Fig 5.2 Deformation distribution in the chassis frame model-1

5.2 Ansys Results of Chassis Frame Model-2

The fig 5.4 shows the equivalent von-mises stress development in the chassis frame model-2. The resulting color image shows that the pattern of stress distribution is similar to the previous model-1. The maximum stress developed in this model-2 is found to be 111.37MPa, which is 4.04% lower than that of the stress in model-1. The height of the rear overhang in this model-2 is higher than that of height in model-1. Due to increase in the height of rear overhang, the perpendicular distance between the line of action of force from the rear end cross member increases. Thus the bending action over the chassis frame increase, instead of direct compressive load. This shows that the impact from the front can be transmitted to the suspension system, instead of transmitting to the frame and its assembling parts completely. Therefore this trend of bending action can avoid damage to the frame and vehicle.

The fig 5.5 shows the deformation distribution in the chassis frame model-2. The resulting image shows that the distribution of deformation in this model-2 is similar to that of deformation in model-1. The maximum deformation developed in this model-2 is found to be 0.854mm, which is 16.6% higher than the previous model-1. Though the deformation increases, it is very less and is better than occurrence of damage to the vehicle and passengers in the vehicle. Thus this model is well preferable over the previous model-1.

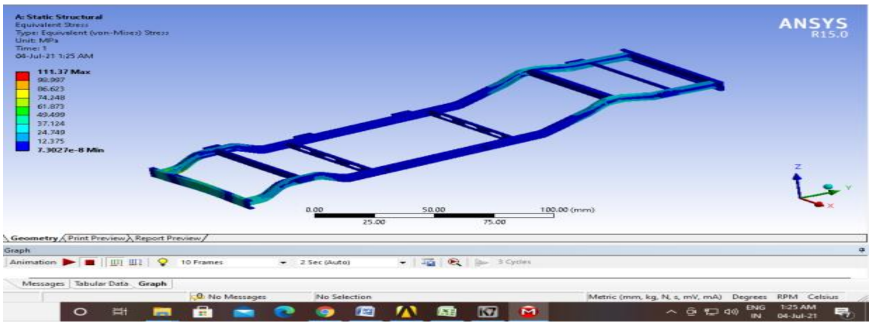

Fig 5.4 Equivalent von-mises stress distribution in the chassis frame model-2

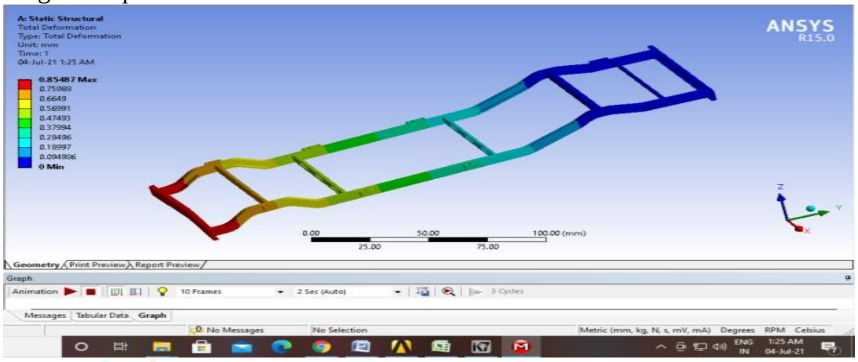

Fig 5.5 Deformation distribution in the chassis frame model-2

5.3 Ansys Results of Chassis Frame Model-3

The fig 5.7 shows the von-mises stress distribution in the chassis frame model-3. The resulting image shows that the pattern of stress development is similar to the previous models. The maximum von-mises stress developed in this model-3 is found to be 104.36MPa, which is 6.3% lower than that of stress in chassis model-2.

The fig 5.8 shows the deformation developed in the chassis frame model-3. The resulting color image shows that the deformation distribution in this model-3 is similar to that of deformation in the previous models. The maximum deformation developed in this model-3 is found to be 0.946mm, which is 10.7% higher than that of deformation in model-2.

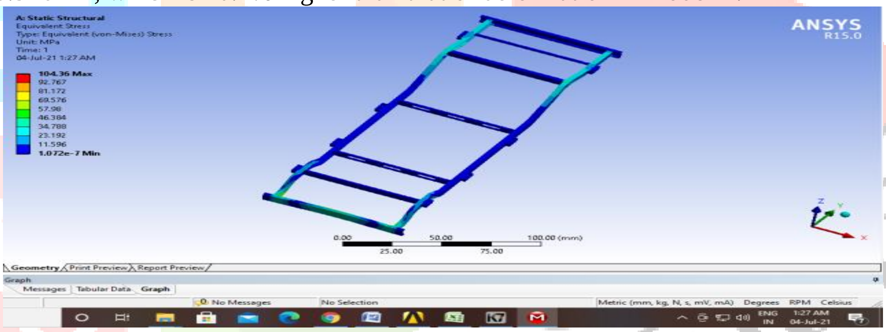

Fig 5.7 Equivalent von-mises stress distribution in the chassis frame model-3

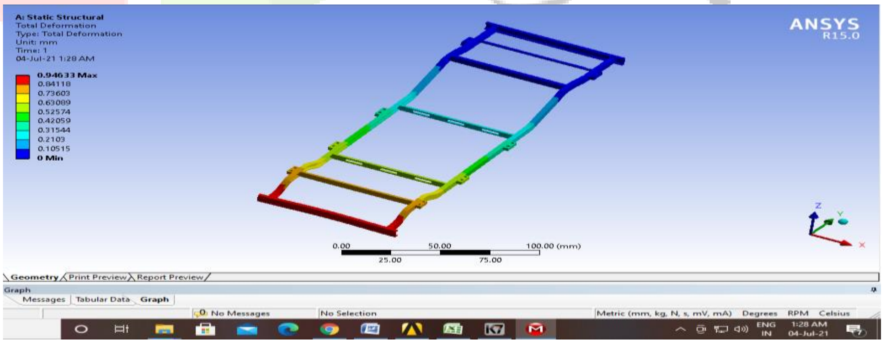

Fig 5.8 Deformation distribution in the chassis frame model-3

5.4 Ansys Results of Chassis Frame Model-4

The fig 5.10 shows the von-mises stress distribution in the chassis frame model-4. The resulting image shows that the pattern of stress development is similar to the previous models. The maximum von-mises stress developed in this model-4 is found to be 97.34MPa, which is 6.7% lower than that of stress in chassis model-3. The stress intensity is decreased in this model, but the area under higher stress values is observed to be increased, especially towards the rear overhang which can be seen with expansion of color representation.

The fig 5.11 shows the deformation developed in the chassis frame model-4. The resulting color image shows that the deformation distribution in this model-4 is similar to that of deformation in the previous models. The maximum deformation developed in this model-4 is found to be 0.997mm, which is 5.3% higher than that of deformation in model-3.

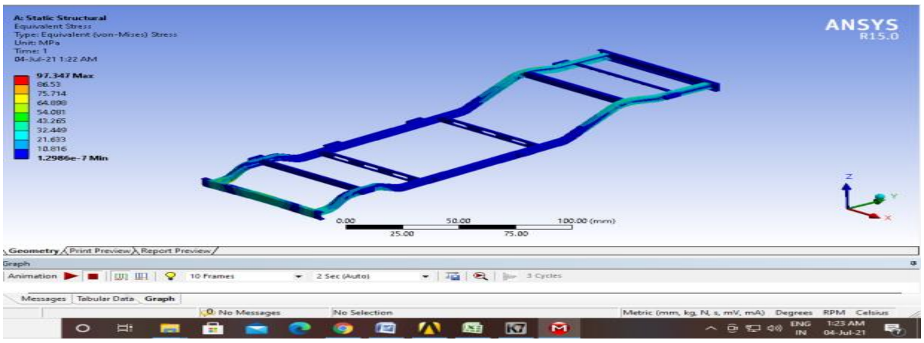

Fig 5.10 Equivalent von-mises stress distribution in the chassis frame model-4

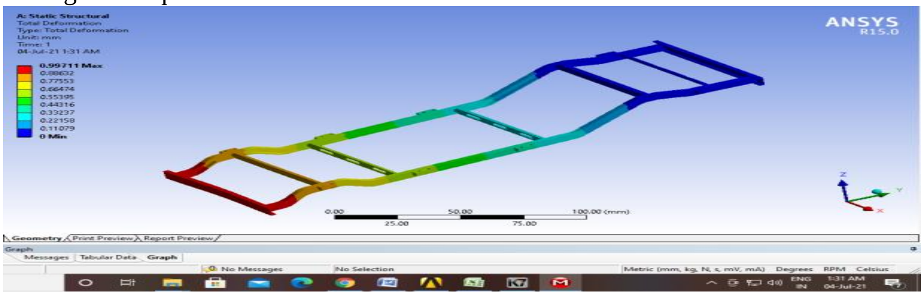

Fig 5.11 Deformation distribution in the chassis frame model-4

5.5 Ansys Results of Chassis Frame Model-5

The fig 5.13 shows the von-mises stress distribution in the chassis frame model-5. The resulting image shows that the pattern of stress development is similar to the previous models. The maximum von-mises stress developed in this model-5 is found to be 95.02MPa, which is 2.3% lower than that of stress in chassis model-4. The stress intensity is decreased in this model, but the area under higher stress values is observed to be increased, especially towards the rear overhang which is similar to the previous model-4, but still with higher area.

The fig 5.14 shows the deformation developed in the chassis frame model-5. The resulting color image shows that the deformation distribution in this model-4 is similar to that of deformation in the previous models. The maximum deformation developed in this model-5 is found to be 1.02mmmm, which is 2.4% higher than that of deformation in model-4.

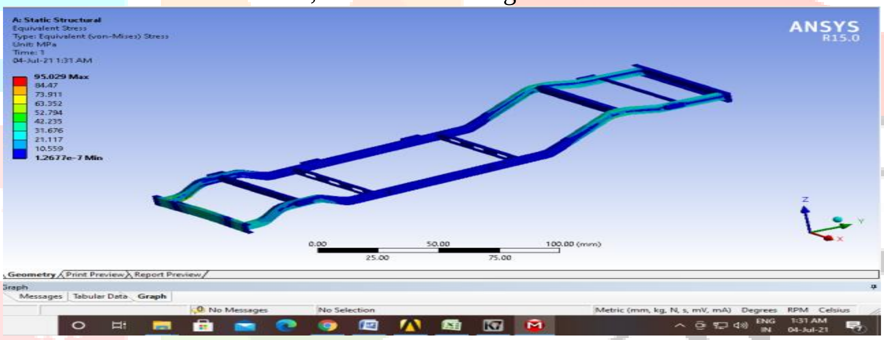

Fig 5.13 Equivalent von-mises stress distribution in the chassis frame model-5

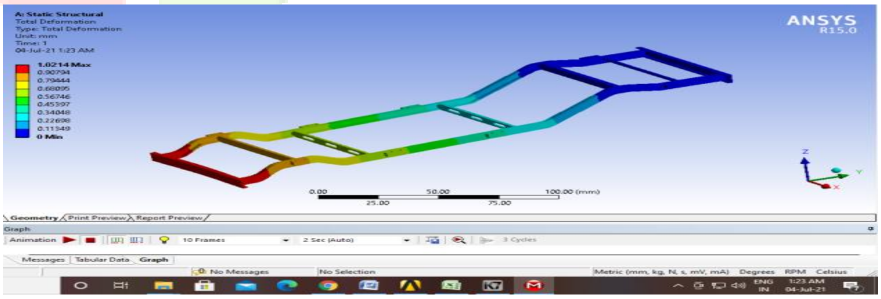

Fig 5.14 Deformation distribution in the chassis frame model-5

5.6 Ansys Results of Chassis Frame under Eccentric Loading

5.6.1 Ansys Results of Chassis Frame under Eccentric Loading Case-1

The fig 5.16 shows the von-mises stress distribution in the chassis frame under eccentric loading action case-1. The resulting color image shows that the stress distribution though seems to be similar to that of stress distribution in the previous model-5, there exist a difference with uneven distribution among the side members of the frame, that the side member which is towards one side of the frame is under higher stress intensities. In this case the external forced is considered to be applied on 50% of the front cross member of the frame. The maximum stress developed in this case is found to be 97.22MPa, which is developed at the cross section of the side member where the front overhang gets started to raise. Due to eccentric load action, there develops a bending action towards one side (direction of eccentric load) in addition to bending action towards the ground. But this effect is very less with just 2.3% higher than that of total front impact load (model-5).

The fig 5.17 shows the deformation developed in the chassis frame under eccentric load case-2. The resulting color image shows that the deformation is not uniformly distributed in the chassis frame due to eccentric load action. The maximum deformation developed in this case-1 is found to be 1.25mm, which is 22.4% higher than that of deformation in the chassis model-5.

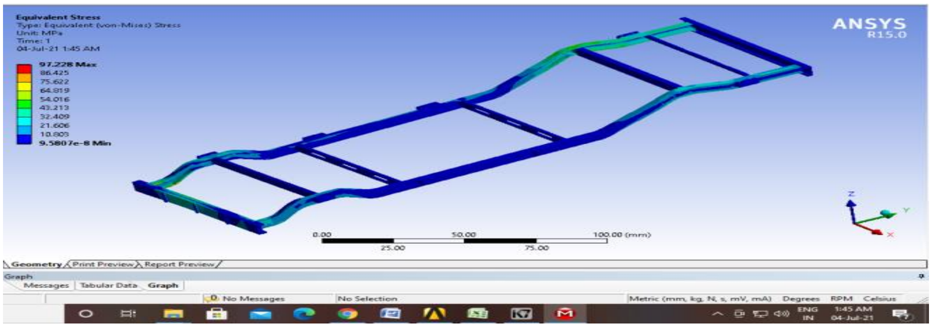

Fig 5.16 Equivalent von-mises stress distribution in chassis frame under eccentric load case-1

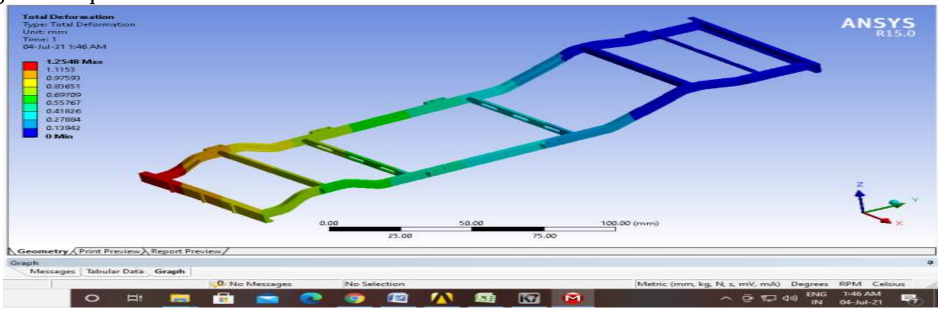

Fig 5.17 Deformation distribution in chassis frame under eccentric load case-1

5.6.2 Ansys Results of Chassis Frame under Eccentric Loading Case-2

The fig 5.19 shows the equivalent von-mises stress distribution in the chassis frame under eccentric load case-2. The resulting color image shows that the pattern of stress distribution seems to be similar to that of stress distribution in the previous models, but some difference can be observed with higher stress intensities in one of side member towards the direction of load action and in portion of front cross member. The maximum stress developed in this case-2 is found to be 141.4MPa, which is 45.4% higher than that of stress in chassis under eccentric loading case-1. In the previous case of eccentric loading case-1, the part of the load on front cross member at the connection of side member leads to direct axial force over respective side member and remaining portion of load acting close to the middle of front cross member is counter balanced by first part. Thus the effect on the chassis frame in this case-2 is less compared to the effect on previous case-1.

The fig 5.20 shows the deformation distribution in the chassis frame under eccentric loading case-2. The resulting image shows that the deformation is maximum on the part of the front cross member and this portion is higher than that of the chassis in eccentric loading case-2. The maximum deformation developed in this case-2 is found to be 1.14mm, which is 8.4% lower than that of the chassis under eccentric loading case-1. This is due to increase in resistance of the chassis to bend towards the ground, which is due to resistance of chassis frame towards the longitudinal twisting.

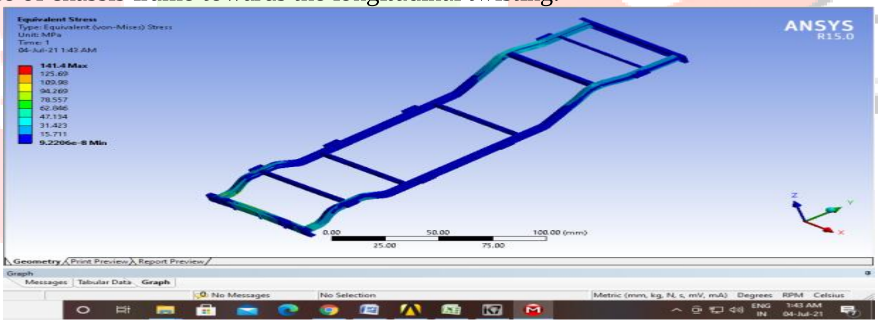

Fig 5.19 Equivalent von-mises stress distribution in chassis frame under eccentric load case-2

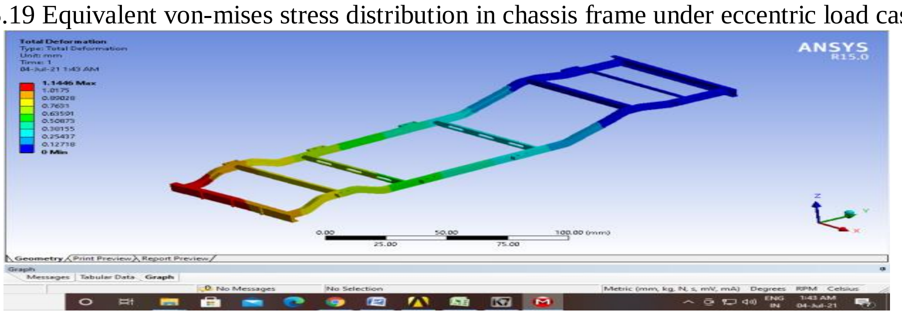

Fig 5.20 Deformation distribution in chassis frame under eccentric load case-2

5.6.3 Ansys Results of Chassis Frame under Eccentric Loading Case-3

The fig 5.22 shows the von-mises stress distribution in the chassis frame under eccentric load case-3. The stress distribution is uneven between side members. The rear overhang portion of the side member is under higher stress intensity with a maximum magnitude of 89.13MPa, which is 6.2% lower than the stress developed in the normal force on entire front chassis and also 8.3% and 36.9% lower than stress developed in the previous eccentric loading cases 1&2. Because due to the eccentric loading action up to only 25% from the end of front cross members, the load leads to direct compressive kind of action over side member towards which the load is developed.

The fig 5.23 shows the deformation distribution in the chassis frame under eccentric load case-3. The deformation developed is found to be higher in the portion of the front cross member toward which the load is applied. The maximum deformation developed in this case-3 is found to be 1.36mm, which is 8.8% and 18.8% higher than the eccentric load case-1and case-2.

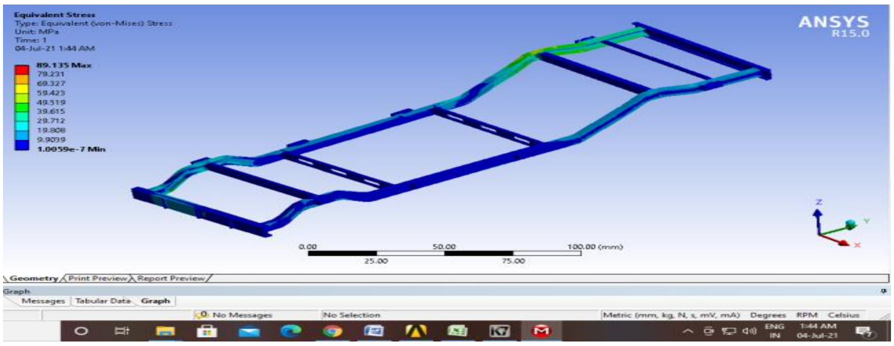

Fig 5.22 Equivalent von-mises stress distribution in chassis frame under eccentric load case-3

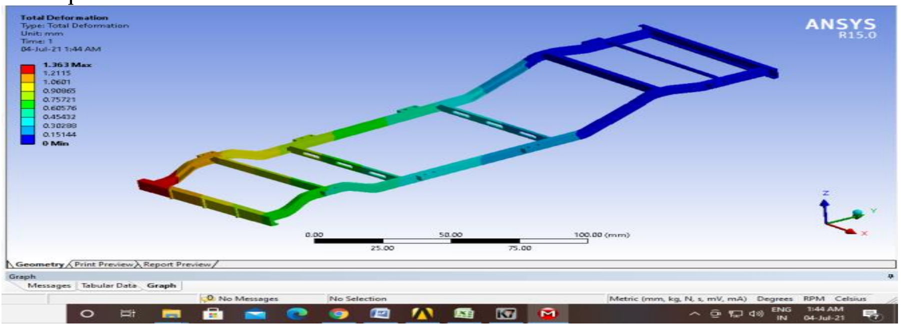

Fig 5.23 Deformation distribution in chassis frame under eccentric load case-3

5.7 Ansys Results of Modified Chassis Frame under Eccentric Loading

5.7.1 Ansys Results of Modified Chassis Frame under Eccentric Loading Case-1

The fig 5.25 shows the equivalent von-mises stress distribution in the modified chassis under eccentric loading case-1. The resulting color image shows that the pattern of stress distribution in this modified chassis is similar to that of stress in normal chassis under same eccentric load case-1. Due to provision of additional angle members connecting the front cross members to side members the stress intensity developed in the chassis got reduced. The angle members contributes in transferring the load from front cross member to opposite member (opposite to side of eccentric load). Thus the stress intensity decreases with a maximum magnitude of 77.53MPa, which is 20.2% lower than that of stress in the chassis without angle members.

The fig 5.26 shows the deformation development in the modified chassis provided with angle members under eccentric load case-1. Though the pattern of deformation development is similar to that of deformation in existing chassis model under same eccentric load case-1, the uneven distribution is reduced due to additional angle members. The maximum deformation developed in this modified chassis is found to be 1.19mm, which is 4.8% lower than that of deformation in existing chassis under eccentric load case-1.

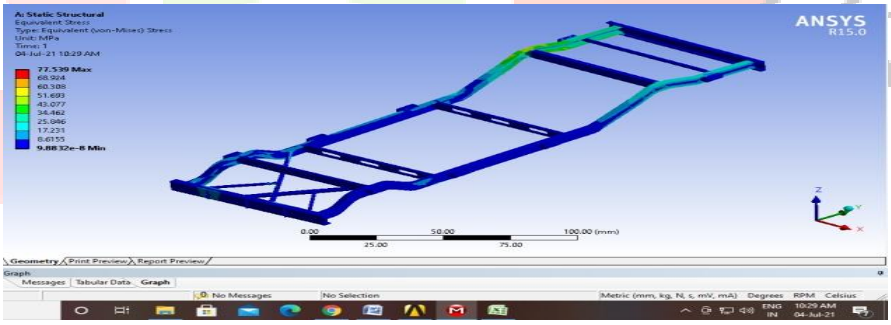

Fig 5.25 Equivalent von-mises stress distribution in modified chassis frame under eccentric load case-1

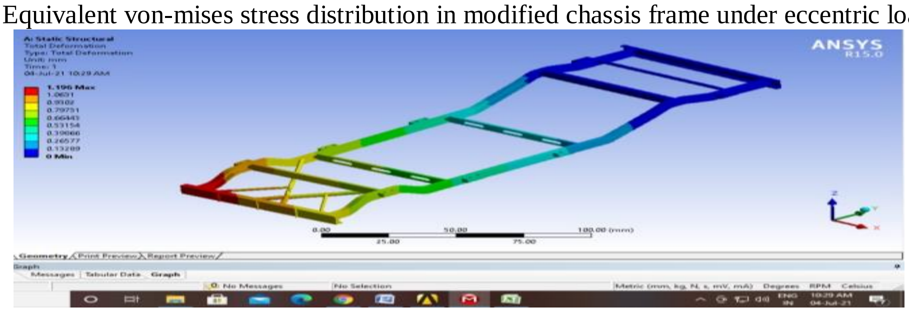

Fig 5.26 Deformation distribution in modified chassis frame under eccentric load case-1

5.7.2 Ansys Results of Modified Chassis Frame under Eccentric Loading Case-2

The fig 5.28 shows the equivalent von-mises stress distribution in the modified chassis under eccentric loading case-2. The resulting color image shows that the pattern of stress distribution in this modified chassis is similar to that of stress in normal chassis under same eccentric load case-2. Due to provision of additional angle members connecting the front cross members to side members the stress intensity developed in the chassis got reduced. The angle members contributes in transferring the load from front cross member to opposite member (opposite to side of eccentric load). Thus the stress intensity decreases with a maximum magnitude of 67.17MPa, which is 52.4% lower than that of stress in the chassis without angle members under case-2.

The fig 5.29 shows the deformation development in the modified chassis provided with angle members under eccentric load case-2. Though the pattern of deformation development is similar to that of deformation in existing chassis model under same eccentric load case-2, the uneven distribution is reduced due to additional angle members. The maximum deformation developed in this modified chassis is found to be 1.091mm, which is 4.63% lower than that of deformation in existing chassis (without angle members) under eccentric load case-2.

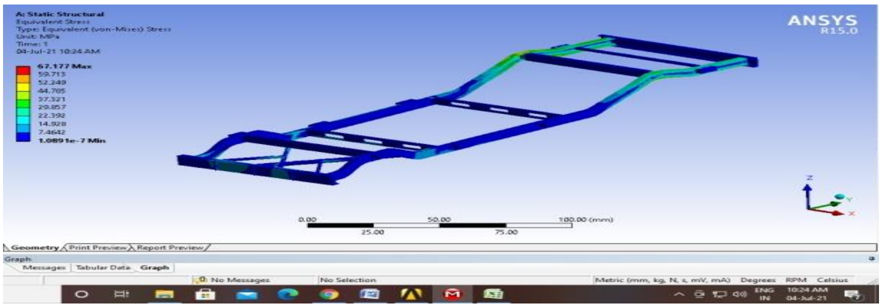

Fig 5.28 Equivalent von-mises stress distribution in modified chassis frame under eccentric load case-2

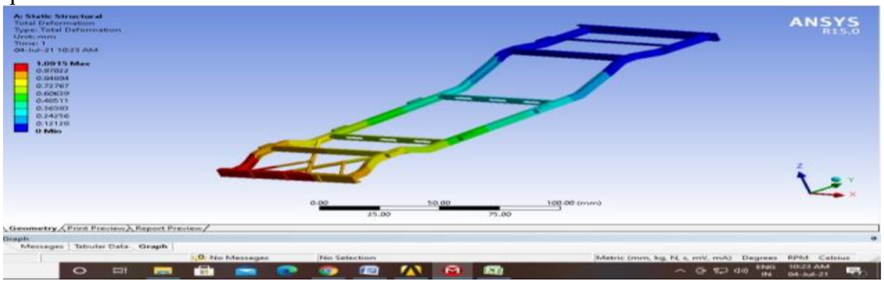

Fig 5.29 Deformation distribution in modified chassis frame under eccentric load case-2

5.7.3 Ansys Results of Modified Chassis Frame under Eccentric Loading Case-3

The fig 5.31 shows the equivalent von-mises stress distribution in the modified chassis under eccentric loading case-3. The resulting color image shows that the pattern of stress distribution in this modified chassis is similar to that of stress in previous cases. The angle members contribute in transferring the load from front cross member to opposite member (opposite to side of eccentric load). Thus the stress intensity decreases, with a maximum magnitude of 88.66MPa, which is 0.5% lower than that of stress in the chassis without angle members under case-3. This is due to the angle members provided. Because of angle members it is observed that the stress due to eccentric load over 25% span of front cross members the effect can be reduced, but the effect due to eccentric load acting over 25% from the ends of front cross member is increased. Therefore, collectively together the results got decreased a little of stress intensity.

The fig 5.32 shows the deformation development in the modified chassis provided with angle members under eccentric load case-3. Though the pattern of deformation development is similar to that of deformation in existing chassis model under same eccentric load case-3, the uneven distribution is reduced due to additional angle members. The maximum deformation developed in this modified chassis is found to be 1.3mm, which is 4.41% lower than that of deformation in existing chassis (without angle members) under eccentric load case-3.

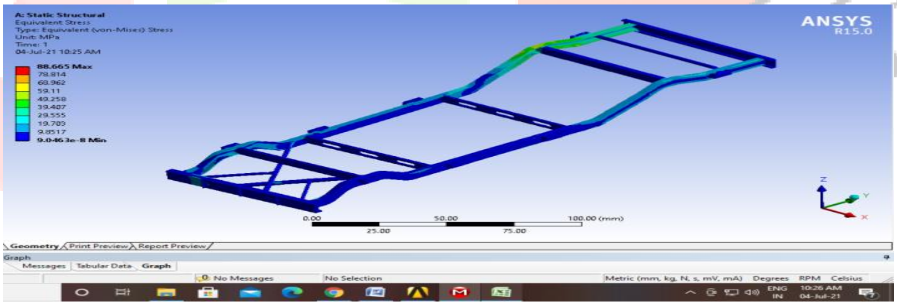

Fig 5.31 Equivalent von-mises stress distribution in modified chassis frame under eccentric load case-3

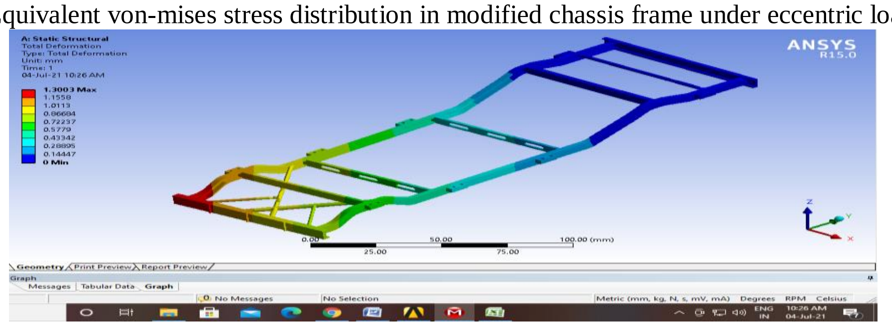

Fig 5.32 Deformation distribution in modified chassis frame under eccentric load case-3

5.8 Effect of ratio of height of rear to front overhangs on stress, deformation and safety factor.

The fig 5.34 shows that the von-mises stress in chassis frame decreases with increase of ratio of height of rear to front overhangs.

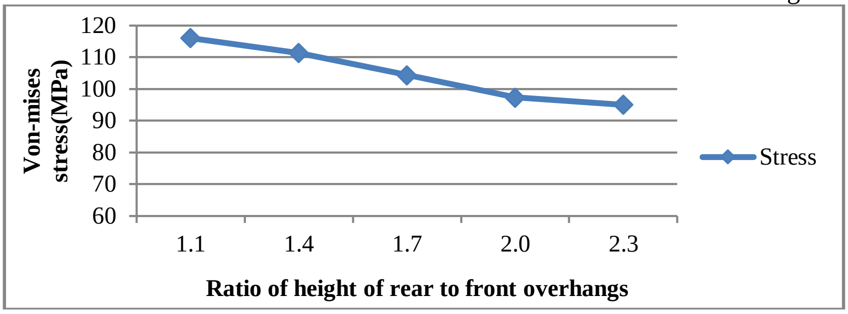

Fig 5.34 Effect of the ratio of height of rear to front overhang on the development of von-mises stress

The fig 5.35 shows that the deformation in chassis frame increases with increase of ratio of height of rear to front overhangs.

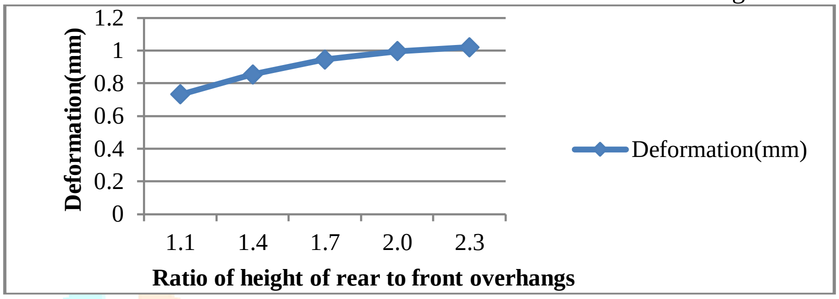

Fig 5.35 Effect of the ratio of height of rear to front overhang on the development of deformation

5.9 Comparison of results under different eccentric loading cases

The fig 5.37 shows that the sequence of effect of eccentric loading in von-mises stress from higher to lower: Eccentric load Case-2, Eccentric Load case-1 and Eccentric Load case-3.

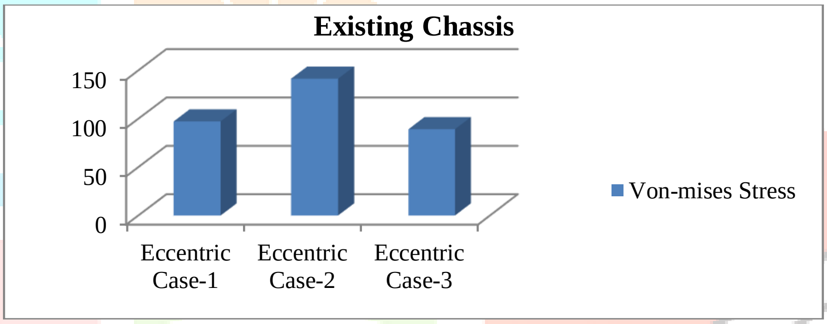

Fig 5.37 Comparison of von-mises stress under different eccentric load cases

The fig 5.38 shows that the sequence of effect of eccentric loading in the development of deformation from higher to lower: Eccentric load Case-3, Eccentric Load case-1 and Eccentric Load case-2.

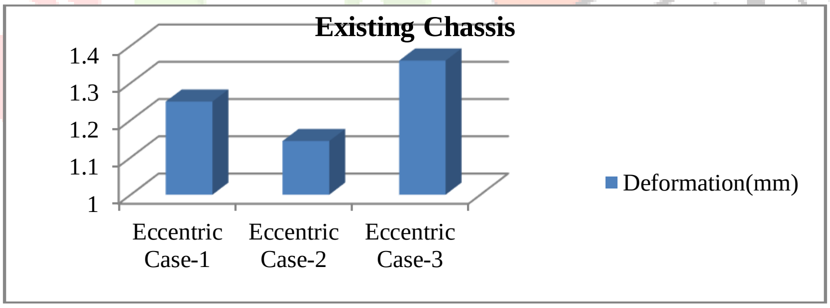

Fig 5.38 Comparison of deformation under different eccentric load cases

The fig 5.39 shows that the sequence of effect of eccentric loading in the attainment of safety factor from higher to lower: Eccentric load Case-3, Eccentric Load case-1 and Eccentric Load case-2.

5.10 Comparison of existing and modified chassis frame results under eccentric loading

The fig 5.40 shows that the von-mises stress development in the modified chassis is less than existing chassis model in all the considered cases of eccentric loading.

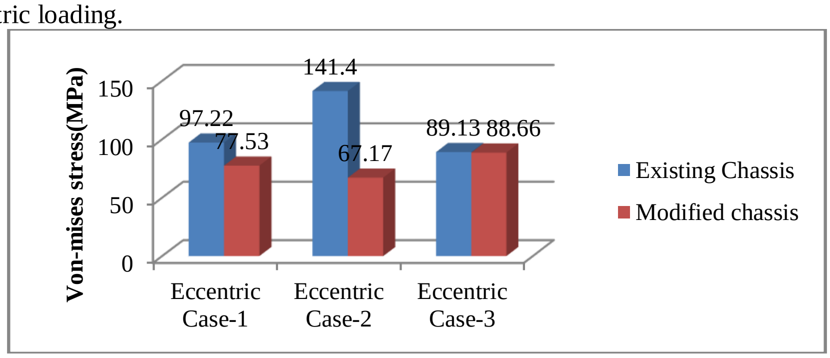

Fig 5.40 Comparison of von-mises stress between existing modified chassis

The fig 5.41 shows that the deformation development in the modified chassis is less than existing chassis model in all the considered cases of eccentric loading.

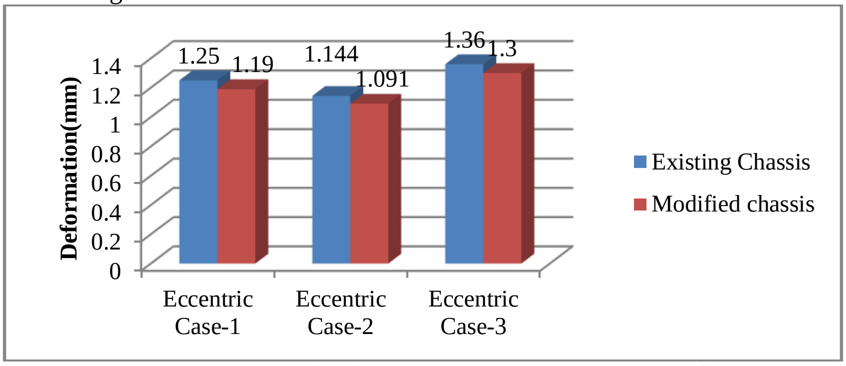

Fig 5.41 Comparison of deformation between existing modified chassis

VI. CONCLUSIONS

The following conclusions were drawn by conducting series of analysis tests on existing chassis frame by varying the ratio of height of rear to front overhang (fixed front) and also eccentric loading action on both existing and modified chassis frame.

- The equivalent von-mises stress in the chassis frame decreases with increase of ratio of height of rear to front overhang. The von-mises stress developed is minimum in chassis model-5 with a magnitude of 95.02MPa, which is 18.1% lower than that of stress in chassis model-1 (High stresses model).
- The deformation in the chassis frame increases with increase of ratio of height of rear to front overhang. The deformation developed is minimum in chassis model-1 with a magnitude of 0.732mm, which is 28.3% lower than that of deformation in chassis model-1 (highly deformed model).
- Comparing three eccentric loading cases, the deformation in all the cases is within acceptable range, but the maximum von-mises stress development in eccentric load case-2 is 48.4% and 58.6% higher than the stress in eccentric load case-1 and case-3.
- The modified chassis frame provided with angle members is developed with a maximum stress of 67.17MPa under eccentric load case-2, which is 52.5% lower than the stress in existing chassis model under the same eccentric load case-2.
  Thus concluded with the modified chassis with 2.3 ratio of height of rear to front overhang is optimum design under eccentric loading conditions.

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