Fatigue Analysis of Tractor Trailer Chassis

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Abstract - *Tractor trailers are agricultural products transporting vehicle, this vehicle used to transport agricultural products from one place to other place. Therefore, it is essential to do static fatigue analysis of trailer chassis. Based on analysis the life estimation of trailer chassis can be done.*

In this project work, the trailer chassis model has been designed using 3D modeling software CATIA. The designed 3D model is imported into FEA software Ansys. On imported 3D model the pre-processed, post-processed and solving are performed in FEA software Ansys

Meshing model with different element size are performed in pre-processing on imported 3D model, in next stage, the boundary condition on meshed model are applied. In last stage, solving for different loading with varied element size is performed.

For 3 different fatigue theories, those three different fatigue theories are Goodman, Gerber and Soderberg, the analysis results are obtained for 3 different load scenarios with varied element size.

3 different loads are consider in this project are, 6Tonne, 12 Tonne and 18 Tonne. Analysis results have demonstrated that the chassis has 10^6 cycles of life time for 12 Tonne of loading without fatigue failure. It is observed that there is a fatigue failure for 18 Tonne loading. The convergence method is used to verify the accuracy of analysis results for element size: 15 mm, 10mm and 5 mm.

The summary of this project work is analysis results are approximate to convergence method and the chassis has lifetime of 10^6 cycles for 12 Tonne load without fatigue failure.

Key Words: Fatigue analysis, Fatigue life.

1. INTRODUCTION

Trailers are non self propelled vehicle used for transport goods from one place to other place, these trailers are hooked to a self propelled vehicle and those may be truck or tractor or in some cases trailer are pulled by human or animals in some places that depends where it is used.

Trailers are of different types, those are classified based on the number of wheels a trailer has and other type of classification are based on specific function of trailer.

Tractor trailer are vehicle used to transport agricultural products from one place to other place, this trailer are play very important role in India, because India is a agricultural based country, here transport agricultural products play very important role. Now a day's use of trailer are common in India, as explain earlier type of trailer, a two wheeler and four wheeler trailers are use, among two wheeler type trailer are common. Now a day's four wheeler type trailer becoming popular, because of load carrying capacity of four wheeler trailer are more than the two wheeler trailer that is the main advantages of four wheeler trailer.

There is a need of fatigue analysis of trailer chassis to know its lifetime for particular amplitude of loading, this become advantage for a manufacture to make design safe and to fulfill customer demands. To do that, in this project work a fatigue analysis was carried out for three different load cases.

To check the obtained results of three different cases are correct, there is another analysis are carryout that is convergence method, in this convergence method, element size are varied and results are checked. It shows results are converges from element size 15 mm to 5 mm, it can be concluded that the obtained results are approximately correct.

Mohammad Najafiyan et al [1], in this a truck chassis analysis is carried, in this analysis a load is converted into pressure and this became a uniform load applied on to the beams and the stress and deflection results are obtained for three boundary condition. But in this paper there is no fatigue life of the chassis was mentioned for the obtained stress value for the three cases. Bhata ka et al [2], here a tractor trolley chassis failure analysis is carried out for two cases, first cases with the existing model "C" section model analysis is carried and results are obtained and in second case "I" section model analysis was carried and results are obtained, based on the results "I" section has reduced total weight compare to "C" section tractor trolley. Shivakumar M.M et al [3], chassis frame analysis is carried out in this paper three cases are solved those are stress analysis, model analysis and fatigue analysis. After this analysis a chassis frame was modified and the fatigue analysis was carried out, results are improved in modified model than earlier model. J. P. Karrthik et al [4], parabolic leaf spring fatigue life was found using Gerber, Goodman, marrow and Smith Watson Topper (SWT), if the loading was frequently in tensile in nature then a Marrow method was good to find fatigue life, if time histories had zero mean then all three methods gives almost approximately results. Dr. R. Rajappan et al [5], chassis was analyzed for static and model analysis, results was checked and results are well below the critical value, so the analysis shows the chassis was safe for the load acting on the chassis. Manpreet singh bajwa et al [6], here a Tata super ace model chassis was analyzed for static stress analysis and the verification was done using solid mechanics and the results are compare, the obtained results are matched with the software results and the design was safe because the stress value are less than the maximum value. Roslan Abd Rahamn et al [7], Heavy truck chassis was analyzed, here fatigue failure was started because an induced stress was more than safe stress and considered safety factor was lower, in this paper it was mentioned that if the safety factor value changed the chances of failure will be less. N.K.Ingole et al [8], self weight reduction of tractor trailer chassis, statics stress analysis was carried for four cases, first case variation in cross sectional areas of cross members, in second case variation in cross sectional areas of cross and longitudinal members, in the third case along with second case modification with a changing the position of the cross members of the main frames of chassis and last case cross member and longitudinal members cross sections are varied considerably. As weight reduction was increased with case 2, 3 and 4 respectively, this result less material cost. But manufacturing cost is high for case 4 which is becomes disadvantage. Ms.Kshitija A.Bhat et al [9], failure analysis was carried out for the tractor trailer using FEM approach, analysis results shows tractor trailer was failed due to the self weight of tractor trailer, so there is a need to improvement. Hemant B. Patil et al [10], stress and displacement results was calculated for varying thickness 4mm, 5mm and 6 mm, changed the 4th cross member position and changed 5th cross member thickness to 5mm. Results was viewed and the best method to adopt was change thickness of cross member at critical point.

2. THEOROTICAL CALCULATION

Pressure due to external load

$$P = \frac{W * g}{A}$$

Where

P is pressure due to external load in MPa

W is external load acted on trailer chassis in kg

g is acceleration due to gravity, 9.81 m/s^2

A is surface area on which load is acting

P_d Pressure due to dead weight acting on the chassis

$P_d = 1.23 * 10^{-3}$ MPa

Case1: for 6 Tonne load.

$P_1 = 3.35 * 10^{-2}$ MPa

Case2: for 12 Tonne load.

$P_2 = 6.70 * 10^{-2}$ MPa

Case3: for 18 Tonne load.

$P_3 = 1.00 * 10^{-1}$ MPa

3. FINITE ELEMENT ANALYSIS

A finite element analysis is carried out for a tractor trailer chassis to know its fatigue life.

Table -1: Material Property of A 36 steel

Density	7850 Kg/m^3
Modulus of elasticity	200GPa
Poisson's ratio	0.26
Yield strength	250MPa
Ultimate strength	414MPa

Boundary condition: First case applying 6 Tonne load ($3.35 * 10^{-2}$ MPa) with dead load of 220kg ($1.23 * 10^{-3}$ MPa) and remote force of 23500N is applied on chassis. Same procedure is carrying out for 12 Tonne and 18 Tonne load instead of 6 Tonne as mention in first case.

Fig 1 shows 3D model of trailer chassis, fig 2 shows meshed model of trailer chassis with an element size of 15mm.

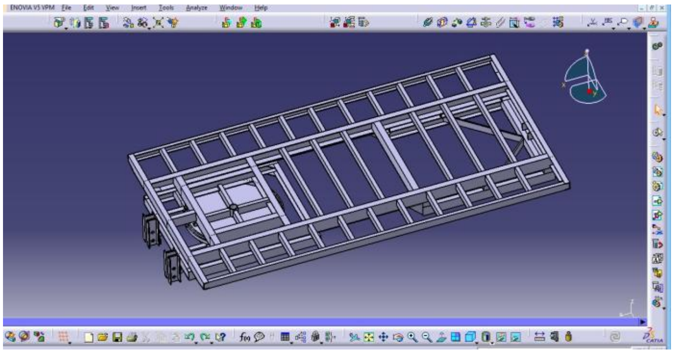

Fig -1: Trailer Chassis Model

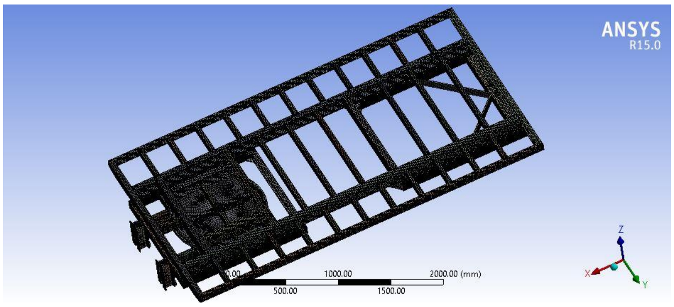

Fig -2: Meshed Trailer Chassis

The fig 3 shows applying boundary condition for 6 Tonne load, dead load 220kg and remote force of 23500N to tractor trailer chassis.

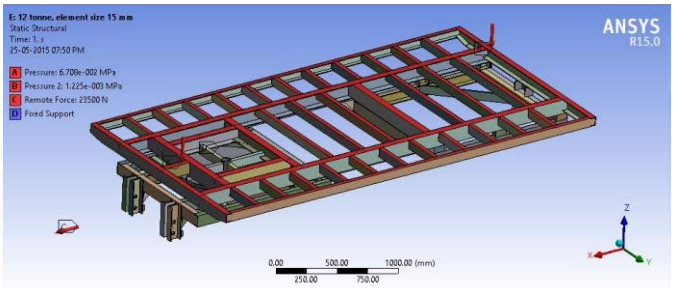

Fig -3: Applying Load and Boundary Condition for 6 Tonne Load

Fig 4 shows equivalent stress 114.92MPa as maximum, 0.00011421 as Minimum equivalent stress, for 6 Tonne load, fig 5 shows the no damage of chassis for 6 Tonne load.

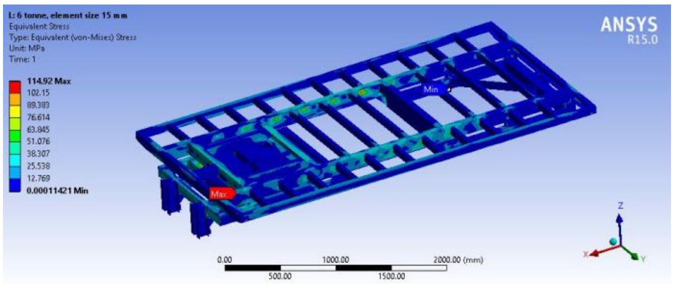

Fig -4: Equivalent Stress for 6 Tonne Load.

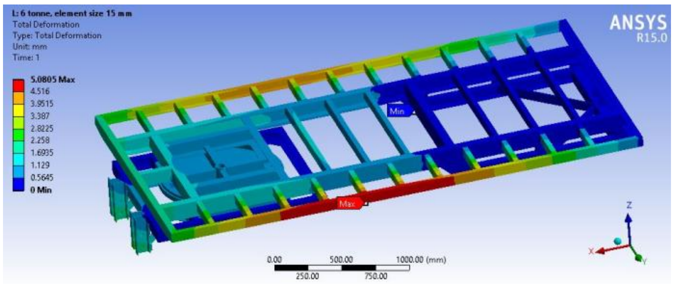

Fig -5: Deformation of Chassis for 6 Tonne Load.

3.1 Fatigue Analysis Results

Case 1: 6 Tonne load

Following figure shows fatigue life cycles and fatigue damage for different loading condition.

Fig 6 shows chassis has life of 10^6 cycles for a fatigue load of 6 Tonne in all three theory those are Goodman, Gerber and Soderberg. Fig 7 shows chassis has no damage for a load of 6 Tonne by use of three theories those are Goodman, Gerber and Soderberg.

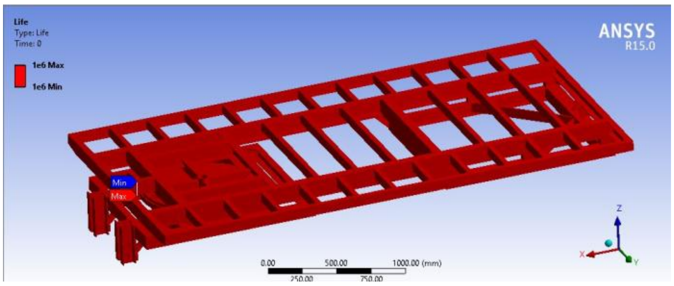

Fig -6: Fatigue Life of a Chassis for 6 Tonne Load

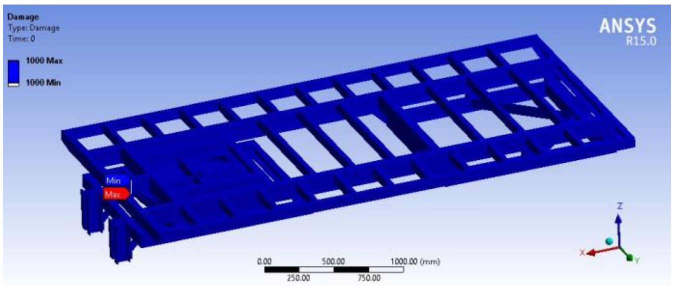

Fig -7: Fatigue Damage of a Chassis for 6 Tonne Load

Table 2 shows results obtained for 6 Tonne load in three fatigue theories, in all theories obtains results are same.

Table -2: Results for 6 Tonne load

Theory	Life cycles		Damage	
	Min	Max	Min	Max
Goodman	10^6	10^6	1000	1000
Gerber	10^6	10^6	1000	1000
Soderberg	10^6	10^6	1000	1000

Case 2: 12 Tonne load

Fig 8 shows chassis has life of 10^6 cycles for fatigue load of 12 Tonne in Goodman and Gerber. Fig 9 shows chassis has no damage for load of 12 Tonne in Goodman and Gerber.

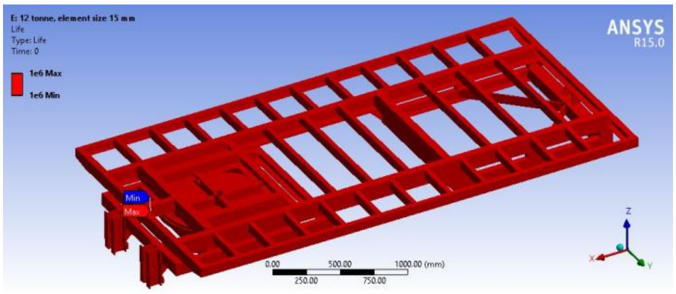

Fig -8: Fatigue Life of a Chassis for 12 Tonne Load in Goodman and Gerber Theories

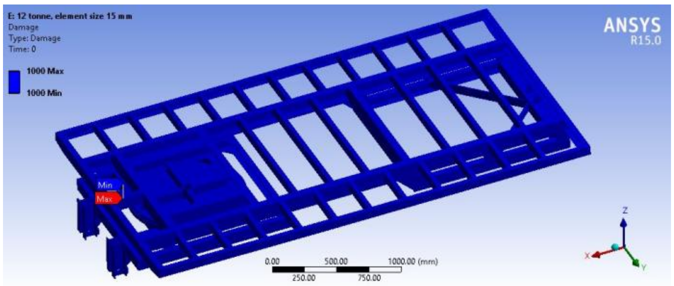

Fig -9: Fatigue Damage of Chassis for 12 Tonne Load in Goodman and Gerber Theories

Fig 10 shows chassis has minimum fatigue life of $2.67*10^5$ cycles and maximum fatigue life of 10^6 cycles for fatigue load of 12 Tonne in Soderberg theory. Fig 11 shows chassis has minimum fatigue damage of 1000 and maximum fatigue damage of 3742 for load of 12 Tonne in Soderberg theory.

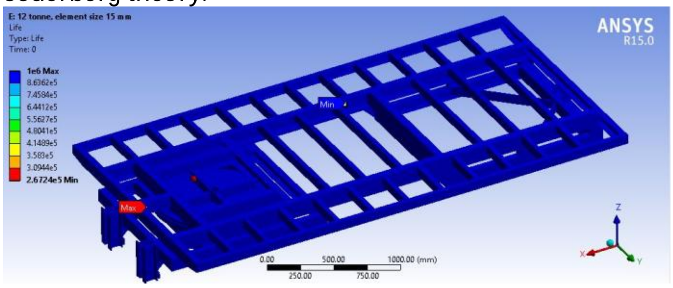

Fig -10: Fatigue Life of a Chassis for 12 Tonne Load in Soderberg Theory

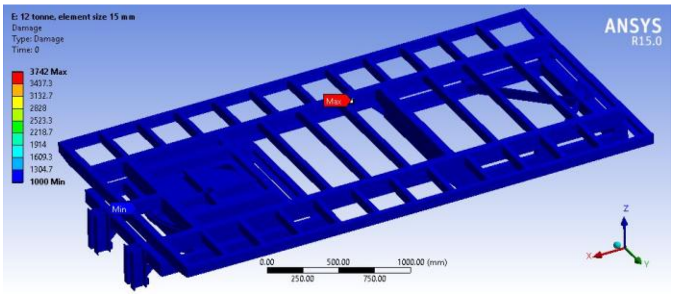

Fig -11: Fatigue Damage of Chassis for 12 Tonne Load in Soderberg Theory

Table 3 shows results obtained for 12 Tonne load in three fatigue theories, for Goodman and Gerber results are same that is fatigue life cycles 10^6, fatigue damage of 1000. Soderberg theory minimum fatigue life cycle of $2.7*10^6$ and maximum of 10^6 cycles, minimum fatigue damage of 1000 and maximum fatigue damage of 3742.

Table -3: Results for 12 Tonne load

Theory	Life cycles		Damage	
	Min	Max	Min	Max
Goodman	10^6	10^6	1000	1000
Gerber	10^6	10^6	1000	1000
Soderberg	$2.7*10^6$	10^6	1000	3742

Case 3: 18 Tonne load

Fig 12 shows chassis has minimum fatigue life of 21584 cycles and maximum fatigue life of 10^6 cycles for fatigue load of 18 Tonne in Goodman theory. Fig 13 shows chassis has minimum fatigue damage of 1000 and maximum fatigue damage of 46330 for load of 18 Tonne in Goodman theory.

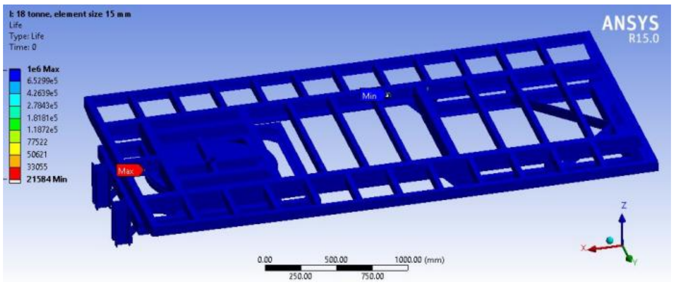

Fig -12: Fatigue Life of Chassis for 18 Tonne Load in Goodman Theory

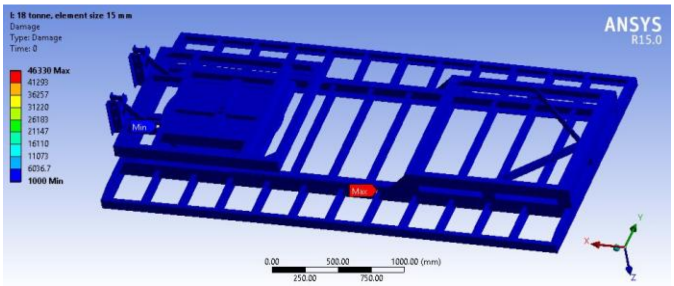

Fig -13: Fatigue Damage of Chassis for 18 Tonne Load in Goodman Theory

Fig 14 shows chassis has minimum fatigue life of $2.4316*10^5$ cycles and maximum fatigue life of 10^6 cycles for fatigue load of 18 Tonne in Gerber theory. Fig 15 shows chassis has minimum fatigue damage of 1000 and maximum fatigue damage of 4112.6 for load of 18 Tonne in Gerber theory.

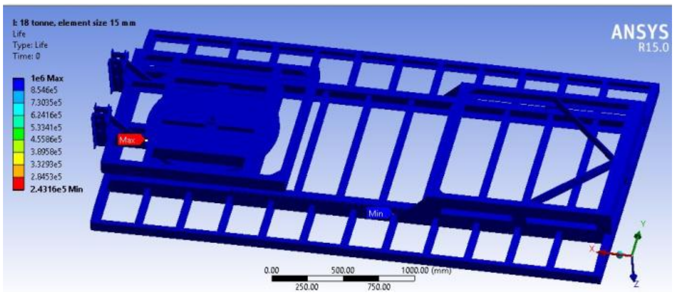

Fig -14: Fatigue Life of Chassis for 18 Tonne Load in Gerber Theory

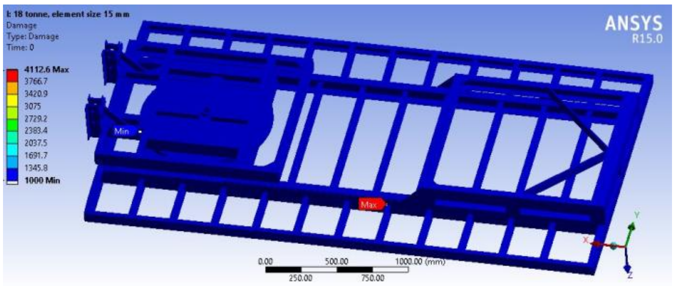

Fig -15: Fatigue Damage of a Chassis for 18 Tonne Load in Gerber Theory

Fig 16 shows chassis has minimum fatigue life of 531.28 cycles and maximum fatigue life of 10^6 cycles for fatigue load of 18 Tonne in Soderberg theory. Fig 17 shows chassis has minimum fatigue damage of 1000 and maximum fatigue damage of 1.88 $*10^6$ for load of 18 Tonne in Soderberg theory.

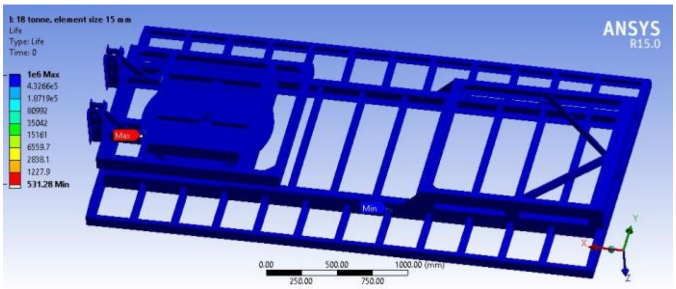

Fig -16: Fatigue Life of Chassis for 18 Tonne Load in Soderberg Theory

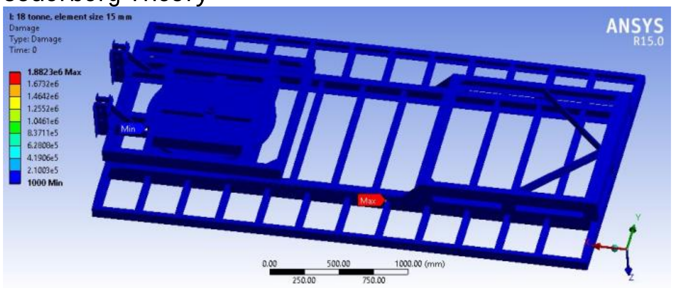

Fig -17: Fatigue Damage of Chassis for 18 Tonne Load in Soderberg Theory

Table 4 shows results of 18 Tonne load on tractor trailer chassis, for three different theories.

Table -4: Results for 18 Tonne load

Theory	Life cycles		Damage	
	Min	Max	Min	Max
Goodman	21584	10^6	1000	46330
Gerber	$2.4*10^6$	10^6	1000	4112.6
Soderberg	531.3	10^6	1000	$1.8*10^6$

3.2 Convergence method

H type convergence method is used to verify the FEA results, by varying element size: 15mm, 10mm and 5mm.

Table 5 shows comparing results for varying element size for 12 Tonne load case. Here 12 Tonne load case with varied element size results are only shown, because 18 Tonne load chassis has fatigue failure. For 12 Tonne load chassis has 10^6 life cycles, to verify obtained FEA results for 12 Tonne loading, convergence results shown.

Table -5: Comparing results for varying element size for 12Tonne load

Theory		Element size 15 mm	Element size 10 mm	Element size 5 mm
Goodman (Life cycles)	Min	10^6	10^6	10^6
	Max	10^6	10^6	10^6
Goodman (Damage)	Min	1000	1000	1000
	Max	1000	1000	1000
Gerber (Life cycles)	Min	10^6	10^6	10^6
	Max	10^6	10^6	10^6
Gerber (Damage)	Min	1000	1000	1000
	Max	1000	1000	1000
Soderberg (Life cycles)	Min	$2.67*10^5$	$2.34*10^5$	$2.67*10^5$
	Max	10^6	10^6	10^6
Soderberg (Damage)	Min	1000	1000	1000
	Max	3742	4264.1	3741.6

CONCLUSION

There is a need of tractor trailer chassis fatigue analysis, because, failure of tractor trailer chassis due to repeating high loads acting on the trailer chassis. In this project work tractor trailer model is created using modeling software Catia, analysis is carried out by using FEA software like "Ansys 15", for different load condition those are 6 Tonne, 12 Tonne and 18 Tonne with different fatigue theories those are Goodman, Gerber, and Soderberg. One more analysis is carried out by varying element size of 15mm, 10mm and 5mm with 12 Tonne load, to verify obtained FEA results are approximately correct or not.

Following statements are made by use of analysis results

1. In 6 Tonne loading, chassis has no fatigue failure up to10^6 cycles in all three theories.
2. In 12 Tonne loading, there is no fatigue failure up to 10^6 cycles except Soderberg theory. In Soderberg theory shows a fatigue failure starts at some points in chassis for $2.3452*10^5$ cycles.
3. In 18 Tonne loading, chassis shows fatigue failure in all three theories.
4. To check analysis results are approximately correct, one more analysis is carried out that is by varying element size, in this element size are varied with a size of 15mm, 10mm and 5mm and results are verify with previous case analysis results. Results shows element size of 15mm and 5 mm results are almost converges with each

other. When results are almost converges, it can conclude that obtained results are approximately correct from analysis.

Reason of failure in chassis at 18 Tonne load, there is a need of correction that is 1) to increase the thickness of chassis members. 2) Changing the cross section of chassis members. 3) Changing material of chassis.

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