Design of spur gear for beam strength by using composite material tooth

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Abstract : Gear is one of the most reliable power transmission systems in modern industry, operates at various speeds and loads. Breakage of gear tooth is a serious issue. Gear manufactured with alternate material can compensate this problem. With the advent of composite materials, it has been possible to reduce the weight of the spur gear without any reduction in the load carrying capacity. Composites are well suited for spur gear applications due to its high strength to weight ratio, fatigue resistance and hence, less chances of failure. All these have made composites an excellent replacement for the currently used metallic steel as a gear material. The present work is an attempt to provide an exclusive design technique regarding composite spur gear tooth based on an analysis of software affirmation. However, an effort has been taken towards the evaluation of bending stress at the root of the tooth and the total deflection of tooth tip associated with the new construction methodology. The gear tooth is modeling CATIA V5R18 and the same are analyzed under similar conditions using ANSYS (Workbench 16.2) software considering composite and structural-steel as the tooth material. Software based results are presented and compared for the two distinct cases mentioned above.

Key words: ANSYS (Workbench 16.2), CATIA V5R16, Composite, Spur Gear.

Introduction: sanjay k. khavdu et al Main aim of this thesis is of weight reduction of gear mechanism by possible replacing of all metallic gears with composite hybrid gears in that gear mechanism. And calculation of weight is done utilizing ANSYS workbench v11 [3] Himam et al Fabrication and testing of Composite spur gears was done at NASA Glenn Research Centre. To mount to shaft where torque is applied the composite material served as the web of the gear between the gear teeth and a metallic hub. The composite web was secured solely to the inner and outer polygonal hexagonal features that were machined from spur gear which is initially aerospace quality. The testing is done on the Hybrid Gear against an all-steel gear and a mating Hybrid Gear. As a result of the composite to metal fabrication method utilized, the concentricity of the gears were cut back from their initial high preciseness worth. No matter the concentricity error, the hybrid gears operated with success for over three hundred million cycles at ten thousand rpm and 553 in.*lb torque. Though the planning wasn't weight optimized, the composite gears were found to be 20% lighter than the all-steel gears [4] himam et al Did a research study in which Contact stress analysis between two spur gear teeth was studied in different contact positions, representing a pair of mating gears during rotation. A platform has been established to plot a pair of teeth in contact. Each case was represented a sequence position of contact between these two teeth. The platform gives graphic results for the profiles of these teeth in each position and location of contact during rotation. Finite element models were made for these cases and stress analysis was done. The results were presented and finite element analysis results wer\e compared with theoretical calculations, wherever available [5].

Bharat Gupta, Abhishek Choubey, Gautam V. Varde (2012) et al., presented a paper to suggest that, thorough study of contact stress developed between the different matting gears are mostly important for the gear design. They have used Hertz equations which is a analytical method of calculating gear contact stresses, originally derived for contact between two cylinders. So for contact stress they established and determined appropriate models of contact elements, and calculated contact stresses using ANSYS and compared the results with Hertz theory. Conclusions suggest that with increase in module, contact stresses decreases for a pair of spur gears [6-7]

Vivek Karaveer, Ashish Mogrekar and T. Permian Reynolds Joseph (2013) et al., this paper presents the stress analysis of mating teeth of spur gear to find maximum contact stress in the gear teeth. The results obtained from Finite Element Analysis (FEA) are compared with theoretical Hertzian equation values. For the analysis, steel and Grey cast iron are used as the materials of spur gear. The spur gears are sketched, modeled and assembled in ANSYS Design Modeler. As Finite Element Method (FEM) is the easy and accurate technique for stress analysis[8-9], FEA is done in finite element software ANSYS 14.5. Also deformation for steel and Grey cast iron is obtained as efficiency of the gear depends on its deformation. The results shown that the difference between maximum contact stresses obtained from Hertz equation and Finite Element Analysis is very less and it is acceptable. The deformation patterns of steel and Grey cast iron gears depicted that the difference in their deformation is negligible [10-11].

Modeling The computer compatible mathematical description of the geometry of the object is called geometric modeling. CATIA is basically CAD (computer-aided design) software that allows the mathematical description of the object to be displayed and manipulated as the image on the monitor of the computer. While modeling the spur gear tooth, the root of the tooth and the rest portion are designed separately as two different part bodies shown in Fig. 4.1and 4.2 which are again combined to make a single system in ANSYS software through proper contact constraints (shown in Fig. 4.1 and 4.2).

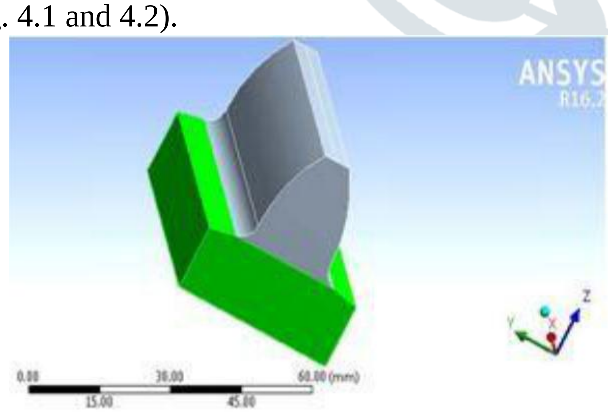


Fig.. Root of the tooth is modeled separately

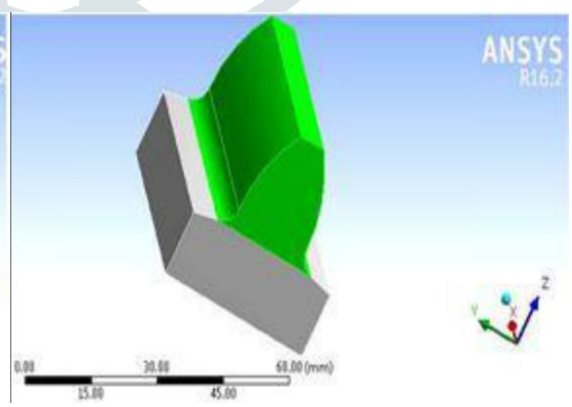


Fig..Tip of the tooth is modeled separately

ANSYS is engineering simulation software that predicts with confidence about the performance of the product under the real-world environments incorporating all the existing physical phenomena. While performing the part of composite analysis, the composite properties were imposed only in the full-length leaves by incorporating the new value of elastic modulus obtained from the rule of mixtures. The layout of static analysis involves meshing, boundary conditions and loading

Meshing : Meshing is basically the division of the entire model into small cell so that at each and every cell the equations are solved. It gives the accurate solution and also improves the quality of solution, Here the element size of 1 mm with medium smoothing is considered for mesh generation. Minimum edge length of the elements is 2.886 mm. Within the solution domain under the Adaptive Mesh Refinement segment, the Max. Refinement Loops is taken as 1 and Refinement Depth as 2. Within the Patch Confirming Method domain the method is taken as Tetrahedrons. For the convergence plot, the maximum allowable change was considered as 4%. The whole geometry is selected for mesh generation and total number of nodes and elements are observed as 51135 and 28947 respectively. Fig.4.3 shows the meshed geometry of the spur gear tooth.

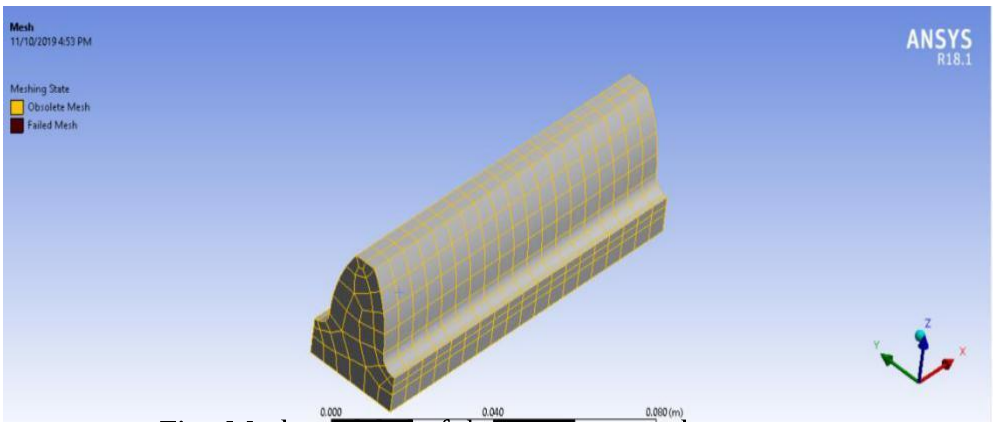


Fig.. Mesh modeled of the spur gear tooth.

Boundary Conditions

Based on the assumptions of Lewis equation, the boundary conditions are set in ANSYS Workbench. The fixed support is used at the root end of the tooth and the force is a plied on the face having components Y and Z directions. The tangential force (F_t) having magnitude 1300N has been introduced with component at Y and Z direction as 1600 N and 1900 N respectively. ompleting the static analysis for both the cases of conventional Steel and Carbon Epoxy composite Steel for given dimensional specifications, the results obtained are summarized below:

5.1. Reduction in weight*:*

Apart from the other benefits, the biggest benefit, however, is mass reduction for using composite materials for the tip of the tooth. While, the mass for the spur gear tooth was 0.6604kg before applying composites; for the next case on application of composite on the tip portion of the tooth while base remains as usual metallic the mass is reduced to 0.5384 kg. So, almost 18.48% weight reduction per tooth can be obtained with the new construction method which can provide a great help towards the modern automobile industry which are focusing on weight reduction.

5.2. Maximum equivalent (Von-Misses) stress:

Simulations are done for the three different torque condition s and the results obtained are similar in nature indicating a comprehensible trend towards a slight increasing value of maximum equivalent

(Von-Misses) stress for composite applications shown in Table 5.1.The results obtained in this connection are as follows shown in the following Fig.

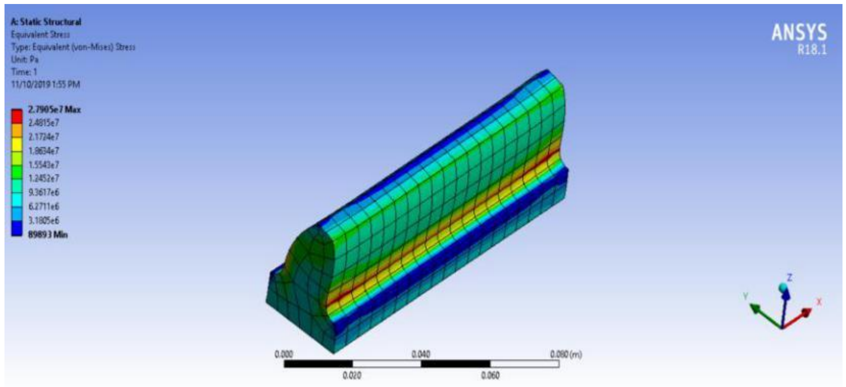
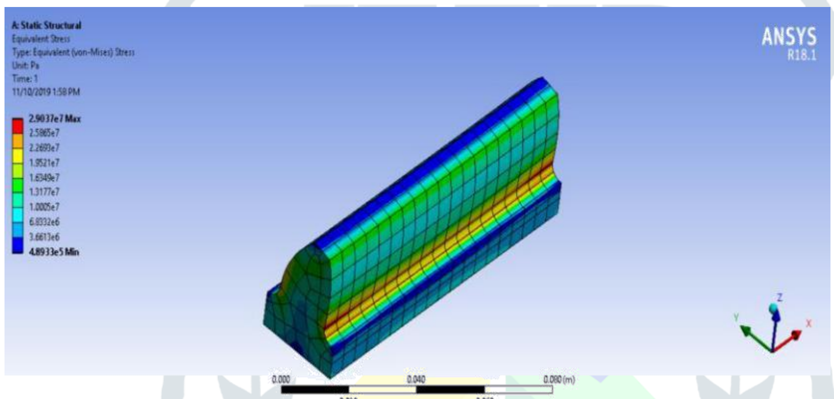


Fig.Maximum equivalent (Von-misses) stresses at a torque of 130N-m @ 2000rpm for structural steel.



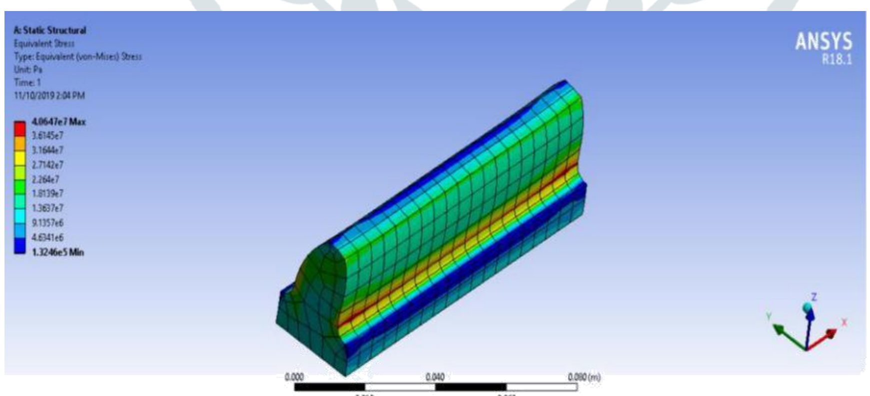


Fig..Maximum equivalent (Von-misses) stresses at a torque of 160 N-m @ 3000 rpm composite and structural steel.

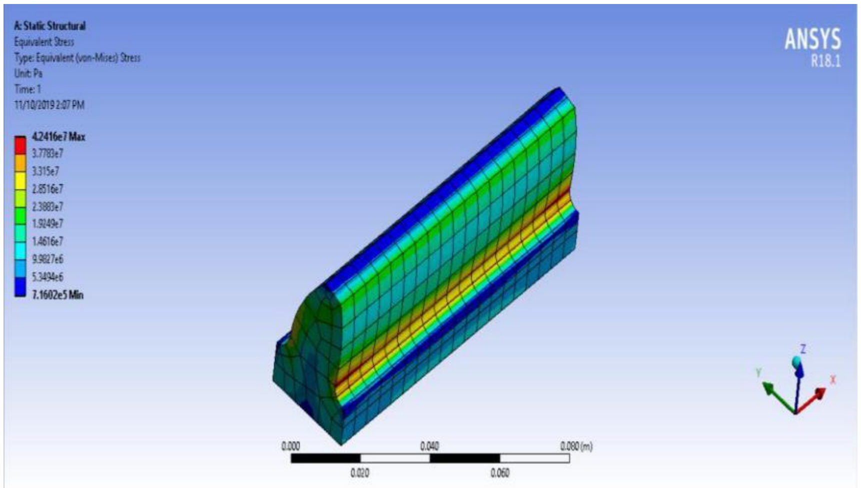
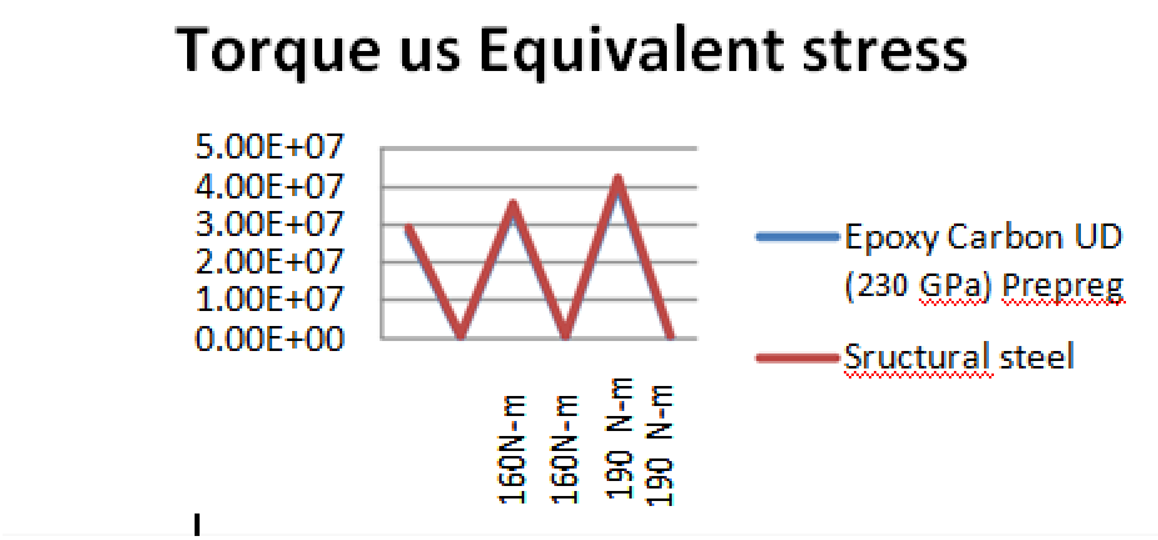


Fig. Maximum equivalent (Von-misses) stresses at a torque of 190 N-m @ 4000 rpm for composite and structural steel.

A graphical representation has been drawn for the conventional steel and Composite based results with torque on X-axis and stress values on Y-axis, shown in the following Fig. 15. There is a slight increase in stress value for the application of carbon fiber.



Torque (N-m)	Theoretical Deflection(m)	ANSYS based Total deformation(m)	Theoretical bending stress(Pa)	ANSYS based bending stress(Pa)
130@2000rpm	$3.91*10^{-6}$	$4.9344*10^{-6}$	$2.61*10^{7}$	$2.79*10^{7}$
160@3000rpm	$4.89*10^{-6}$	$6.0729*10^{-6}$	$3.29*10^{7}$	$3.429*10^{7}$
190@4000rpm	$6.35*10^{-6}$	$7.2113*10^{-6}$	$3.8*10^{7}$	$4.06*10^{7}$

Table.3.2.Calculation of various parameters of Spur Gear Tooth

Parameter	Torque @ rpm (N-m)	With conventional steel gear tooth	Composite gear tooth with conventional steel root of the gear	Increase in stress(Pa)
Max. Equivalent (von-Misses) Stress(MPa)	130 @2000rpm 160@3000rpm 190@4000rpm	$2.79*10^7$ $3.43*10^7$ $4.06*10^7$	$2.9*10^7$ $3.57*10^7$ $4.24*10^7$	$0.11*10^7$ $0.14*10^7$ $0.18*10^7$

Table 5.1.Comparison for steel and composite applications on gear tooth

Directional deformation:

The software based analysis is carried out for the three different standard torque conditions and the results obtained are identical in nature indicating a comprehensible trend towards the decreasing value of total deformation for composite applications. The results obtained are as follows (depicted on the Fig.)

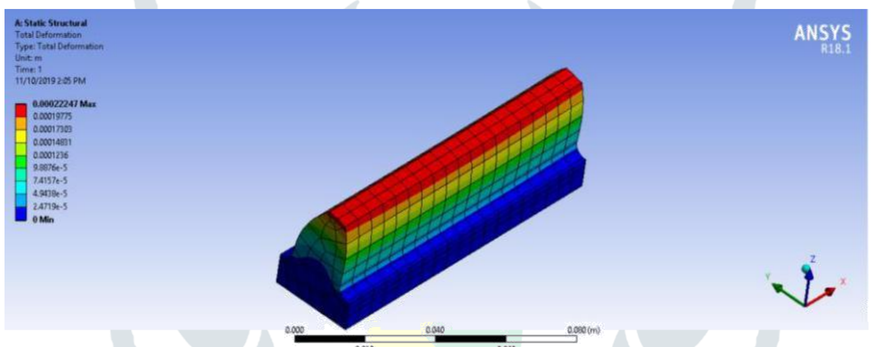


Fig. Total deformation at a torque of 130 N-m @ 2000 rpm of structural steel.

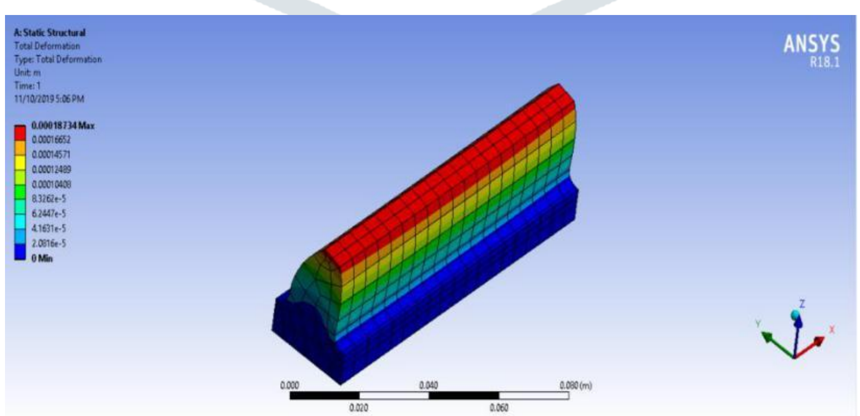


Fig. Total deformation at a torque of 130 N-m @2000rpm with composite and structural steel

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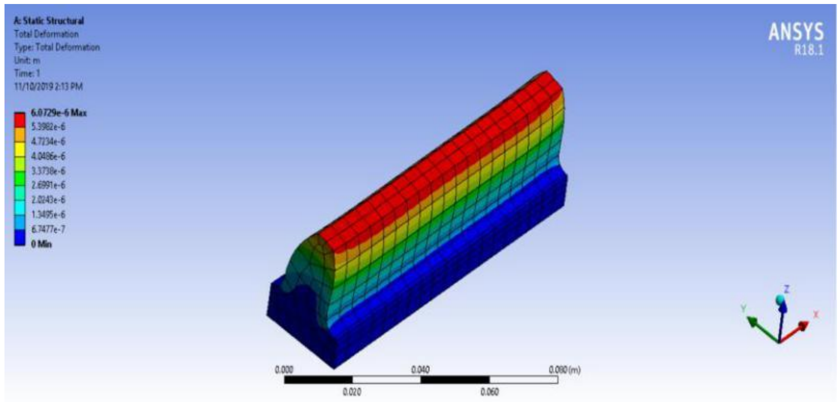


Fig. Total deformation at a torque of 160 N-m@ 3000rpm for composite and structural steel.

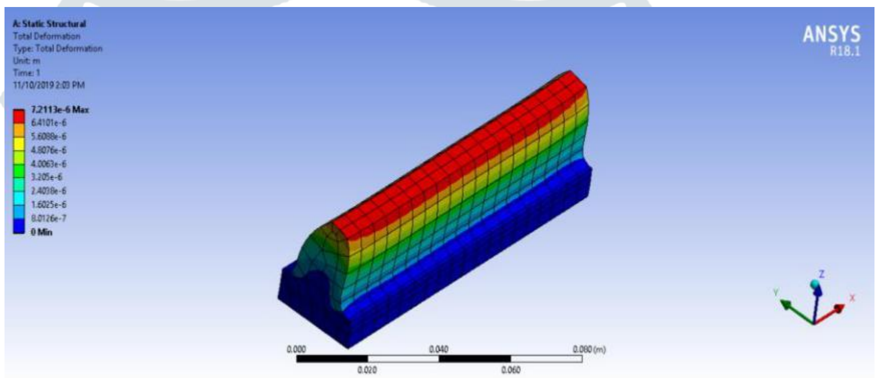
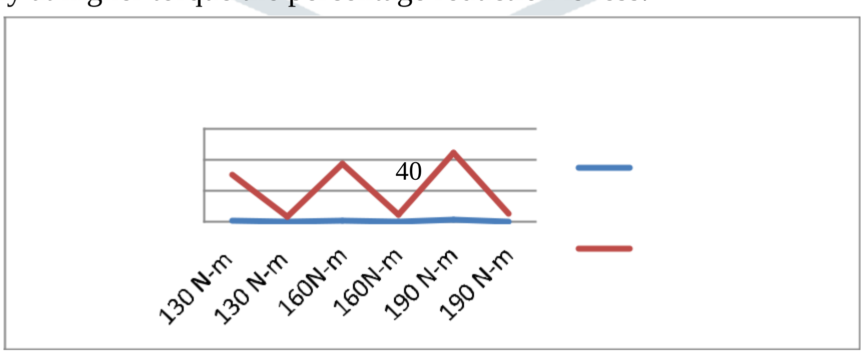


Fig.Total deformation at a torque of 190 N-m @4000rpm with composite and structural steel.

A graphical representation has been drawn for the conventional steel and Composite based results with torque on X-axis and total deformation values on Y-axis, shown in the following Fig. 23. There is a significant decrease in total deformation value for the application of carbon fiber. Interestingly at higher torque the percentage reduction is less.



Parameter	Torque @rpm (N-m)	With conventional Steel gear tooth	Composite tip gear tooth with conventional steel root of the gear	%reduction
Total deformation(mm)	130@2000 160@3000 190@4000	$15.22*10^{-6}$ $18.73*10^{-6}$ $22.24*10^{-6}$	$4.93*10^{-6}$ $6.07*10^{-6}$ $7.2*10^{-6}$	67.2 67.3 67.4
Mass(kg)	-	0.66904	0.5384	0.195

Table Reduction in total deformation per tooth are depicted in the above table.

Conclusion: In this work, the spur gear tooth is modeled in CATIA V5R16 and is analyzed in the Static structural domain of ANSYS software. A conclusion can be drawn on the basis of result discussed on the previous sections is that for the standard design specifications the values of maximum stresses at different torque conditions are well within the safe limit. Apart from that, most importantly the new design method has proposed to manufacture the tip of the gear tooth separately with composites in contrast to use of composites for the entire tooth. It has been observed that a substantial decreasing trend toward the deformation values for composite applications with a negligible increase in maximum stress. This agrees well with the previous works so far done in this context. A reduction in mass of more than 18 % is the one of the prominent benefits with the new method; along with optimum extent towards the manufacturing costs can be achieved as composites being highly expensive than that of steels (almost 2-3 times costlier). Therefore, the new method seems to be beneficial exclusively for modern auto industry as it provides an optimum solution towards weight reduction as well as manufacturing costs. The focus can be given to the joining of metal and composites with different fasteners or suitable adhesive.

References:

1. V.B.Bhandari, Design of machine elements, 2nd ed. New Delhi, India, McGraw Hill Education, ISBN: 0-07-061141-6, 2009, Ch. 17, sec. 17.5, pp. 656-657.
2. VikashChauhan, “A review on effect of some important parameters on the bending strength and surface durability of gear”, International journal of science and research (IJSR) Publications, Vol 6, Issue 3, March 2016 289 ISSN 2250-3153.
3. Shaik Himam Saheb, Annam Vijay Kumar. Finite Element Simulation of Deep Drawing of Aluminium Alloy Sheets. International Journal of Industrial and Manufacturing Systems Engineering.Vol. 2, No. 6, 2017, pp. 83-102.Doi:10.11648/j.ijimse.20170206.13
4. Shaik Himam Saheb “Design Report of A Go Kart Vehicle” International Journal of Engineering Applied Sciences and Technology, Vol. 1, Issue 9, ISSN No. 2455-2143, Pages 95-102

5. V.Rajaprabakaran, Mr.R.Ashokraj, “Spur gear tooth stress analysis and stress reduction”,IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684,ISSN: 2320-334X, pp.38-48.

6. Shubham A. Badkas and NimishAjmera, “Static and dynamic analysis of spur gear”, International Journal of Mechanical Engineering & Technology (IJMET), Volume 7, Issue 4, July–Aug 2016, pp.8–21.

7. M.L .Pavan Kishore, Himam Saheb Shaik “Numerical investigation for influence of pre-twist on stress behavioral characteristics of curved blade” Vibroengineering PROCEDIA, Vol. 22, 2019, p. 153-157. https://doi.org/10.21595/vp.2018.20072

8. Shaik Himam Saheb “DESIGN REPORT OF QUAD BIKE” International Journal of Recent Scientific Research Vol. 8, Issue, 1, Jan 2016.

9. Sankar and nataraj, “Profile modification a design approach for increasing the tooth strength in spur gear”, The International Journal of Advanced Manufacturing Technology, Vol. 55, pp. 1-9, 2011.

10. R.S. Khurmi, J.K. Gupta, Spur gear, A Text Book of Machine Design, S. Chand, Eurasia Publishing House (pvt.) ltd., 2005.

11. AnujNath, A.R. Nayak, “Design and analysis of the composite spur gear”, International Journal of Advanced Technology in Engineering and Science (IJATES), Volume No.03, Issue No. 06, June 2015 ISSN (online): 2348 – 7550.

12. Utkarsh. M. Desai, Prof. Dhaval. A. Patel, “Static and Dynamic Analysis of Composite Material for Spur Gear”,IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 04, 2015 | ISSN (online): 2321-0613.

13. V. Siva Prasad, Syed AltafHussain, V.Pandurangadu, K. PalaniKumar, " Modeling and Analysis of spur gear for Sugarcane Juice Machine under Static Load Condition by Using FEA", International Journal of Modern Engineering Research, July-Aug 2012, Vol-2/4, pp-2862-2866.