Design & Mass Optimization of Gear using Composite material

[1]Bhairavanath Subhash Jadhav, [2]Dattatray P.Kambale

[1]PG Scholar, [2]Assistant Professor
Department of Mechanical Engineering,
Savitribai Phule Pune University, Pune

***Abstract*: Weight optimization has been getting extra ordinary attention, due to the potential to repeatedly generate not only good, but also optimal proposals. Industrialized creativities try hard to develop the optimized product usually by dropping the weight while ensuring they produce cost efficient products that meet their design functionality and consistency. Structural optimization methods like topology optimization along with modern simulation are appropriate gorgeous tackle in product design process. Those tackle also help to trim down product development time. As gears are key essentials in a diversity of industrial applications such as machine, Aviation, Defense, etc. Aim of this exploration is to reduce weight of gear. Optimization of weight has been very critical aspects of any design. It has substantial impact on vehicle performance, fuel efficiency and in spin minimizes the emissions. This dissertation would focal point on the design gap offered by the element practical even as crucial the scenery and scope of the weight optimization more the areas acknowledged during design optimization.**

***Keywords*: Weight Optimization, Composite material, Hyper Mesh, Gear cost optimization, etc.**

I. INTRODUCTION

Topological optimization is a special form of shape optimization .The bracket and spur gear is simplest type of components manufactured and is generally used for transmission of rotary motion between parallel shafts. The spur gear is the first choice option for gears except when high speeds, loads and ratios direct towards other by using the topology optimization.

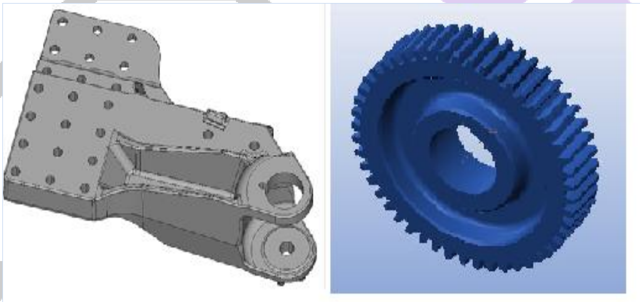


Fig 1.1. Sample Bracket and Gear

In the last decade the use of commercial structural optimization software have increased rapidly. An especially interesting field is topology optimization where optimization methods are used to generate a design concept early in the design process. Various components like bracket, gears are used in most types of machinery and vehicles for the transmission of power. The design of gears is highly complicated involving the satisfaction of many constraints such as strength, pitting resistance, bending stress, scoring wear, and interference in involutes gears etc. The concentration is focused on spur gear sets which are used to transmit motion between parallel shafts because of the reason that out of the various methods of power transmission, the toothed gear transmission stands unique due to its high efficiency, reliable service, transmit large power, compact layout and simple operation. Gear design is an art as well as an engineering science.

Optimisation of weight has been one the critical aspects of any design. It has substantial impact on vehicle performance, fuel efficiency and in turn reduces the emissions. In the automotive domain, companies strive to design light weight vehicles. Besides the saving in the composite material cost, the lighter design helps to reduce fuel consumption (consequently higher fuel efficiency) and better performance.

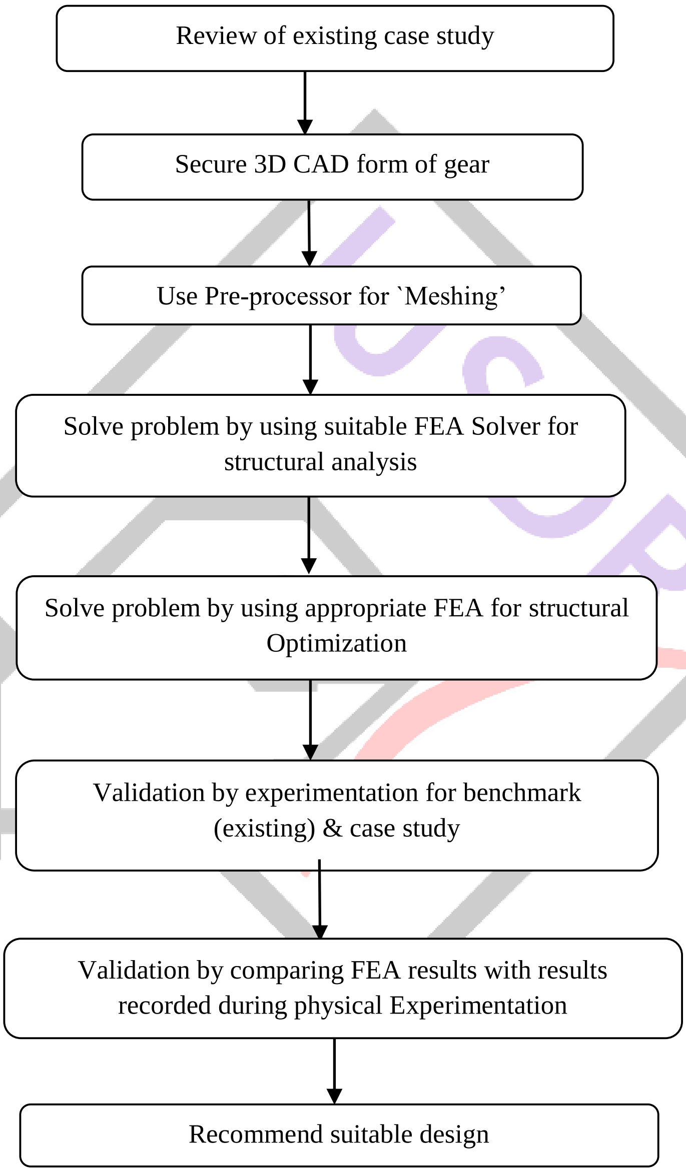
II. SCOPE OF THE WORK

This work would consider engaging “Weight Optimization' as a methodical means for vital scope of weight Optimisation in the obtainable design of the Gears. CAE tools like RADIOSS, Optistruct or solvers shall be deployed to apprehend the outcomes during the investigation stage. The groundwork investigation superior than the results as curbed during structural analysis of the `benchmark' constituent shall be validated.

III. OBJECTIVES OF THE STUDY

The following are the objectives of the study:
1. Weight Optimisation is expected at 2.5% - 5.5% for the gear
2. Benchmarking the stresses or the stress attentiveness above the on hand geometry
3. To classify the areas for weight Optimization
4. Recommending appropriate design bearing in mind qualities of the changes made
5. Validating the Design through alternative methodology that is by experimentation.

IV. PROPOSED FLOW CHART AND METHODOLOGY



V. VIRTUAL PRODUCT DEVLOPMENT OF GEAR

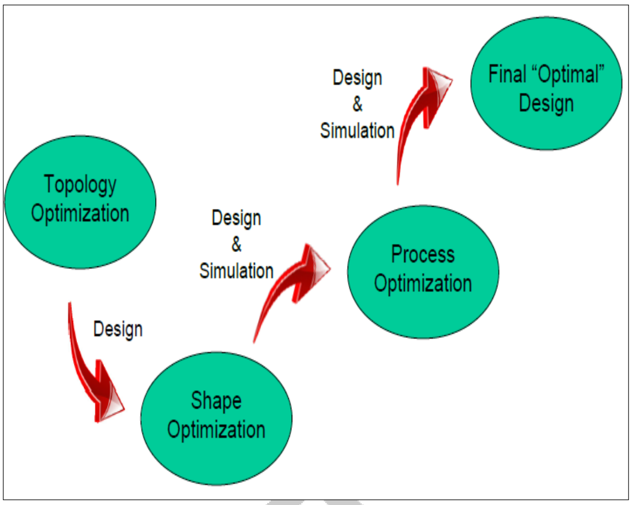


Fig.2.1 Virtual Product Development of Gear

VI. GEAR CALCULATIONS

Torque acting on Pinion, T = 9 Nm = 9000 N-mm
Speed of Pinion, nP = 2400 rpm
Pressure angle, $\phi = 20°$
Number of teeth on Gear, NG = 76
Number of teeth on Pinion, NP = 48
Centre to Centre distance (gear and pinion), L = 98 mm
Face width, F = 22 mm
Pitch circle Diameter of Gear, DG = 108 mm
Pitch circle Diameter of Pinion, DP = 95 mm
Velocity ratio,
V.R. = DG/ DP
= 108/ 95
V.R. = 1.14
Module, m = 1.9 mm
Tangential Load,
Wt = T/ (DP/2)
= 9000/ (95/2)
Wt = 189.47 N
Diametric pitch of Pinion,
Pd = NP/DP
= 48/95
Pd = 0.5
Velocity of Pinion,
V = π* DP*nP/60
= π*95*2400/60
V = 298.3*40 mm/s = 11.46 m/s

Considering, Overload Factor, Ko = 1.25
Dynamic Factor, Kv
Assume Quality number, Qv = 6
Kv = [(A+ √200V)/A] B
Where A = 50 + 56 (1 - B)
B = 0.25*(12 - Qv) 2/3
B = 0.25*(12 - 6) 2/3
B = 0.825
A = 50 + 56 (1 – 0.825)
A = 59.8
Kv = [(59.8+ √ (200*12.43))/59.8] 0.825
Kv = 1.65
Size Factor, Ks = 1

Load Distribution Factor, Km

Km = 1 + Cmc (Cpf Cpm + Cma Ce)

For uncrowned teeth, Cmc = 1

Cpm = 1

Ce = 1

Cpf = 0.025

Cma = A + B*F + C*F2

For commercial enclosed units

A = 0.127

B = 0.0158

C = - 0.93*10-4

Cma = 0.127 + 0.0158*13 + (- 0.93*10-4)*132

Cma = 0.317

Km = 1 + 1 (0.025*1 + 0.31*1)

Km = 1.335

Rim Thickness Factor, KB = 1

Bending Strength Geometry Factor, J = 0.3

Gear Bending Stress

σ = Wt* Ko* Kv* Ks*(Pd/F)*(Km*KB/J)

= 189.47*1.25*1.65*1*(0.5/22)*(1.335*1/0.3)

σ = 39.52 MPa

Composite material used for pinion is EN grade steel with BHN (Brinell Hardness Number) = 230

Applied Bending Strength,

St = 0.7255*HB + 153.63

= 0.7255*229 + 153.63

St = 320.49 MPa

Stress Cycle Factor YN = 1

Temperature factor, YΘ = 1

Reliability factor, YZ = 1.25

Bending factor of Safety,

SF = [(St* YN)/ (YΘ* YZ)]/σ

SF = [(320.49*1)/ (1*1.25)]/130.08

SF = 1.971

Allowable Bending Stress,

σall = [(St* YN)/ (YΘ* YZ)]/ SF

= [(320.49*1)/ (1*1.25)]/1.971

σall = 130.08 MPa

VII.BENDING STRESS ANALYSIS

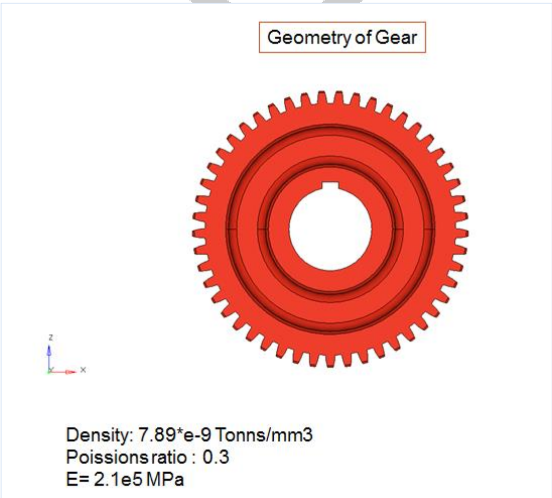


Fig. 3.1.Separate gear

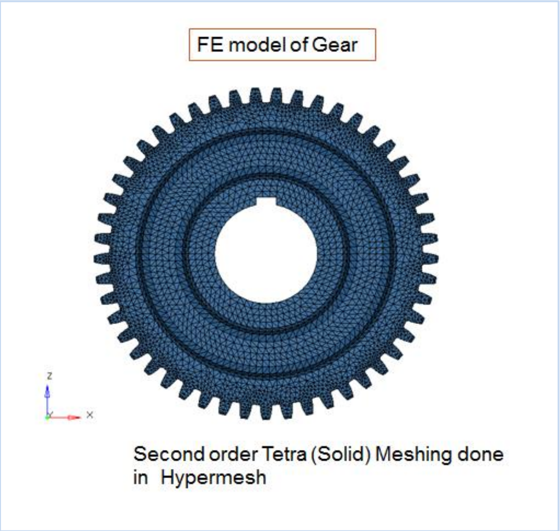


Fig.3.2.Meshing of Spur gear in Hyper mesh

Considered below parameter for meshing as;
1. Element size = 1mm in critical region
= 2mm in other region
3. Element type
C3D10M
(Continuum 3D 10 nodes modified element)

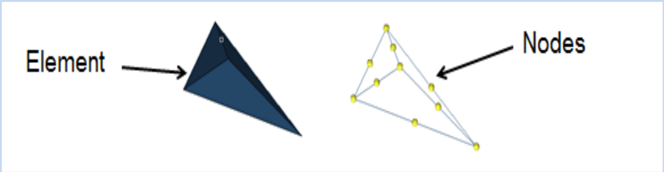


Fig.3.4. Meshing Element Details

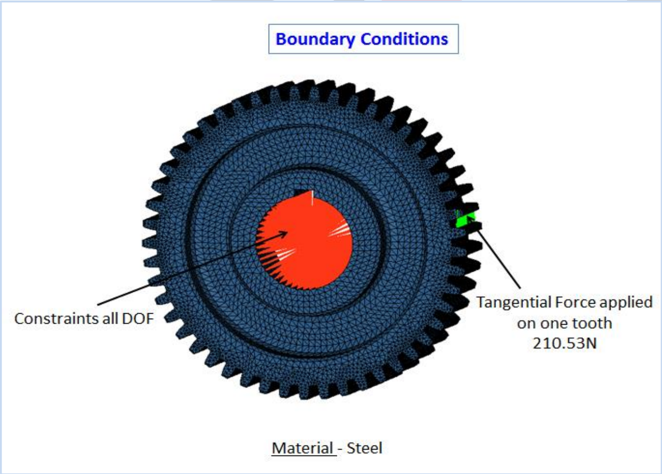


Fig 3.5.Spur Gear upon Application of Boundary Conditions

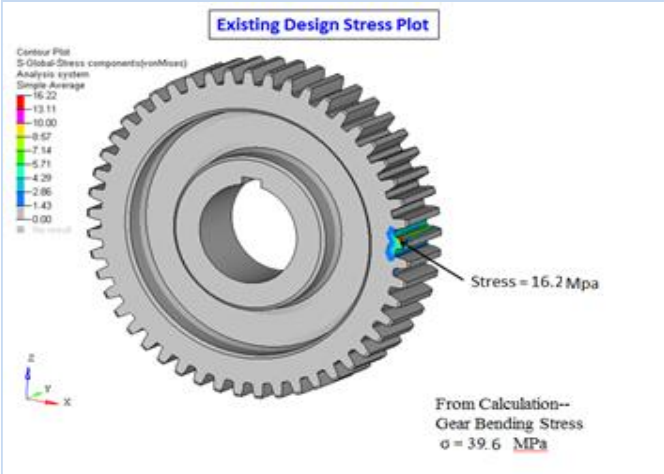


Fig. 3.6.Stress Plot

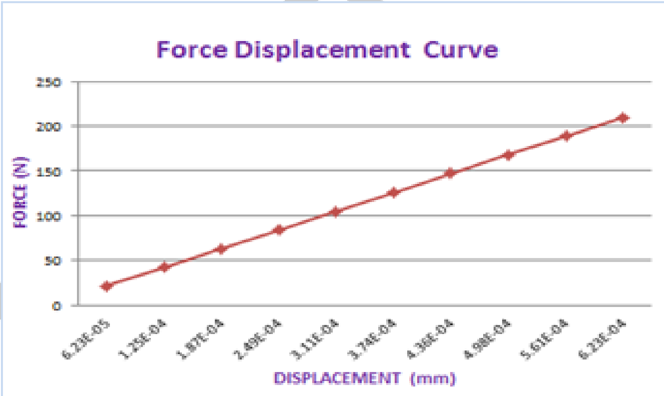


Fig. 3.7.Force Displacement diagram

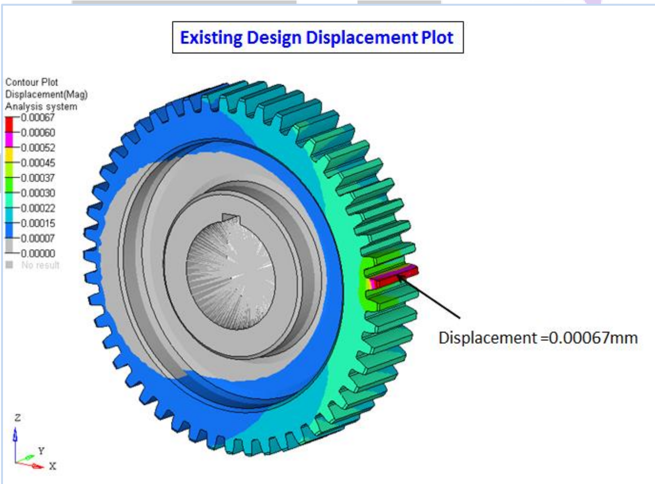


Fig. 3.8.Existing design displacement plot

VIII. CONCLUSION FROM STATIC ANALYSIS

The bending stresses are very less than calculations, so there is scope for optimization. So progressed for optimization in Optistruct result is as shown in fig.3.10 which highlights areas to remove composite material. This is first iteration and after little iteration we will get optimized gear highlighting proper areas to remove composite material.

IX. OPTIMIZATION RESULT

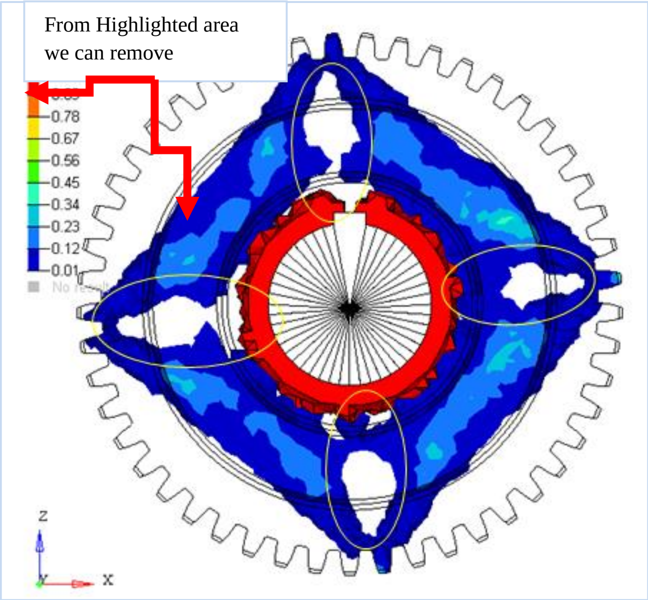


Fig. 3.9.Optimisation result

Fig. 3.10.Proposed design - Geometry

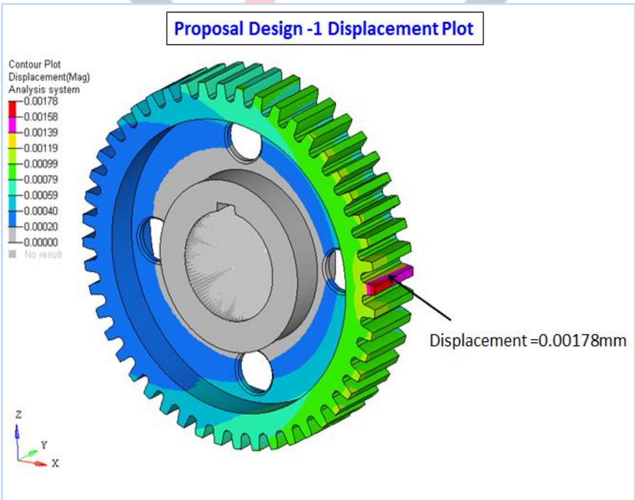


Fig. 3.11.Proposed design-Displacement plot

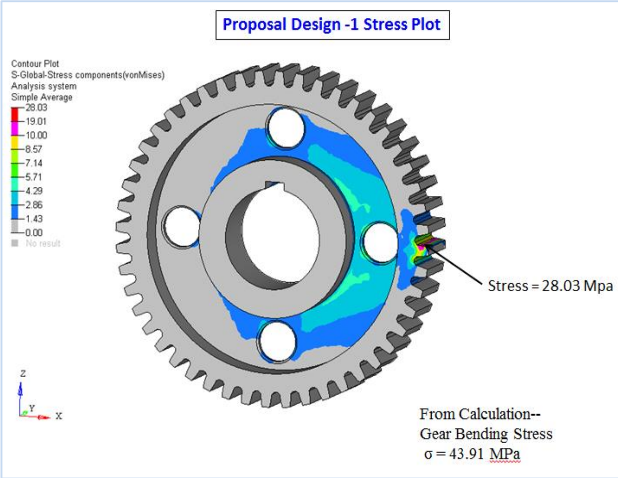


Fig.3.12. Proposed design-Stress plot

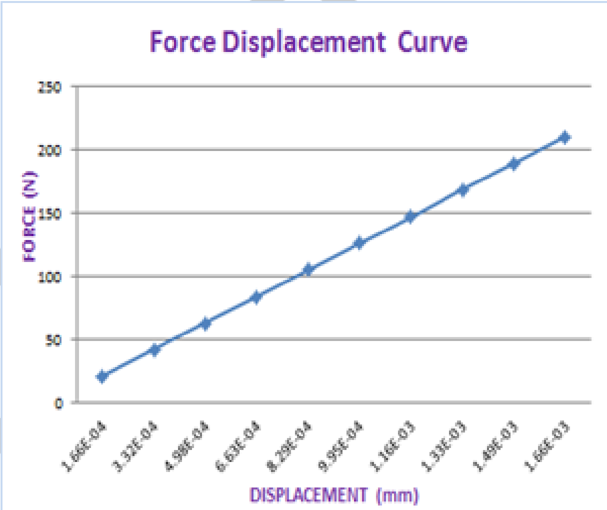


Fig.3.13. Force displacement plot

X. CONCLUSION FROM OPTIMIZED STATIC ANALYSIS

The bending stresses of proposal design -1 are less than the calculations, so there is scope for to reduce the composite material in another location.

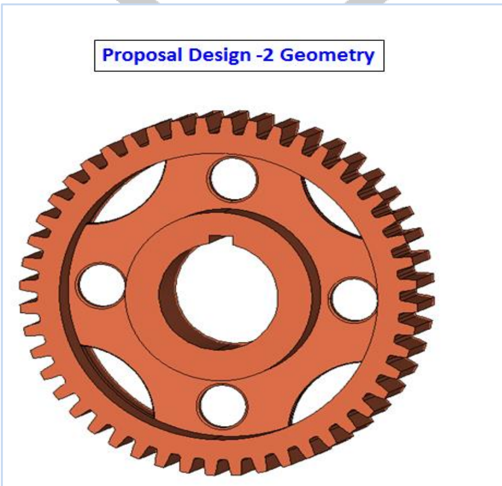


Fig.3.14. Force displacement plot

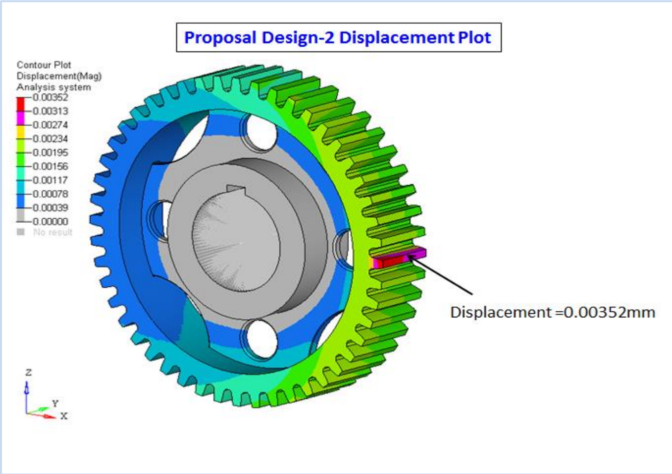


Fig.3.15. Proposal design-2 displacement plot

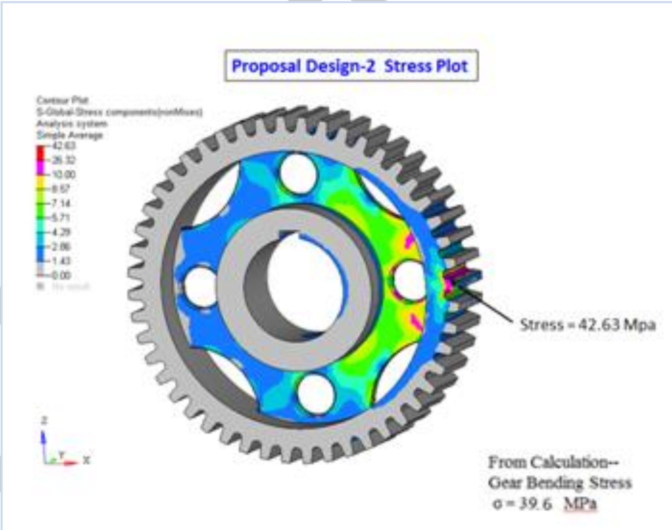


Fig.3.16. Force displacement plot

XI. CONCLUSION

The bending stresses of proposal Design -2 are closer to the calculations and it is acceptable. So this design is safe.

XII. VALIDATION & EXPECTED OUTCOME

In this dissertation we will be validating the rigidity of the component by comparing outcome obtained from conducting tests with results of FEA analysis. On hand design shall be used for experimentation for reasons of accessibility and achievability. Once validated with the on hand design for the given narration restraint, the results shall be appropriate for the optional resolution. Enduring load will be useful and corresponding bend is monitored. The load from the load cells nearby on the UTM mechanism will be applied slowly. Display attached to the mechanism will give a resultant plot for load Vs displacement i.e. rigidity of the gear.

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