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Optimization of gears by using finite element analysis

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ABSTRACT

In this article, we have made an attempt to reduce weight of gears which are the inevitable parts of any Machineries, Automobiles, etc. Weight reduction is the important factor which can attract the customer. In this work, we have removed optimum amount of material in the teeth such that the performance of gear is undisturbed. We have got surprising results when we tried this out with various geometrical cross sections such as circle, square, rectangle, trapezium, rhombus, triangle and hexagon. Interestingly, we found that Square cross section gives better results than others. Then we proceeded with two case studies – Positioning and Sizing. The whole work is done with CAE tools such as PRO-E WF2 (for modeling) and ANSYS 10 (for analysis).The results are presented and discussed with graphical comparisons.

Keywords: Gear; Ansys; Weight reduction; Stress analysis

INTRODUCTION

Gears are most important machine part used in transmission. The major craze in this decade goes to weight reduction. Even though we look for light weight composites, some of the geometrical changes can reduce the weight without disturbing the performance of parts. This way some optimum amount of material can be removed from the gear tooth. But the induced stress during the load has to be calculated to check with the design stress for the stability of the gear. This was done using ANSYS 10.0 platform.

MATERIALS AND METHODS

2. MODELLING

For the analysis, a Spur Gear has been employed. The modeling of the gear was done using PRO-E WF2 with the following specifications

Base Diameter	= 36cm
Shaft Diameter	= 20cm
Pitch circle Diameter	= 42cm
No. of teeth	= 21
Module	= 2
Material	= C45

For the analysis, we have taken a single tooth of the gear and the results are taken based on that**.**

3. ANALYSIS

The following data are given for the analysis of the materials using ANSYS.

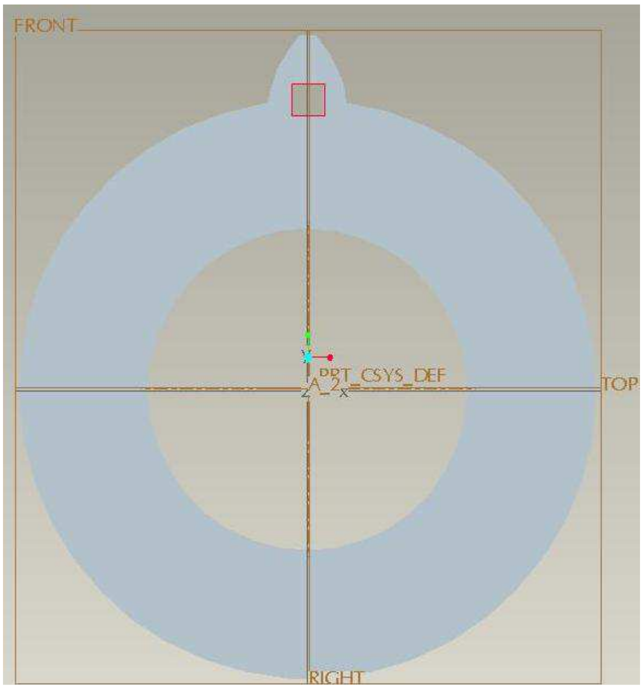
Material Type	= SOLID45
Young's Modulus	= 2.15e5N/mm^2
Poisson Ratio	= 0.3

Density = 7.835 g/cc
Pressure on contact surface = 10 N/mm^2

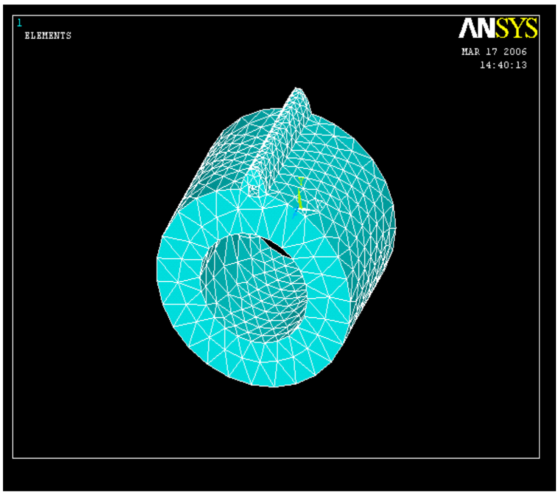
The area of Cross section for all the geometries is kept constant for the perfect comparison.
The following table gives the dimensions of the geometries for the constant area (=400mm^2}

S.No	Geometry	Dimensions
1.	Circle	D=22.57mm
2.	Square	20mm*20mm
3.	Rectangle	10mm*40mm
4.	Triangle	B=20mm(say) h=40mm
5.	Trapezium	B_1=30mm B_2=10mm h=20mm
6.	Hexagon	B=10mm
7.	Rhombus	A=20mm

These dimensions are used to cut the cross sections in the basic gear. That Basic gear is also analyzed for comparison. So, totally 8 models are analyzed. The output results are shown in the next section.



GEAR SHAPE AFTER THE WEIGHT REDUCTION
The square shape was proved as optimum design corresponding to the stresses induced in the gear.

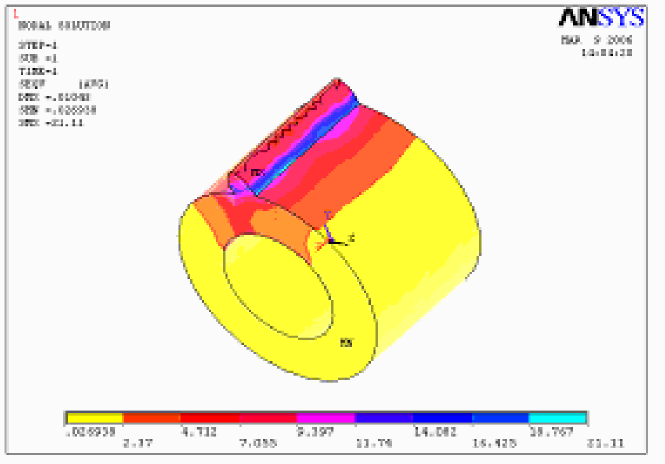


MESHED GEAR WITH SQUARE SHAPED MATERIAL REMOVED

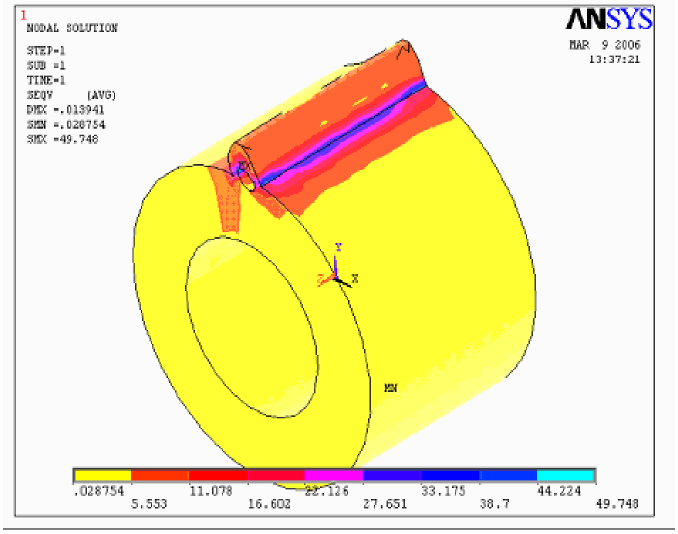
4.ANALYSIS OUTPUT- STRESS

The stress induced in this gear is taken as base line and all the other geometries should give the value less than this.

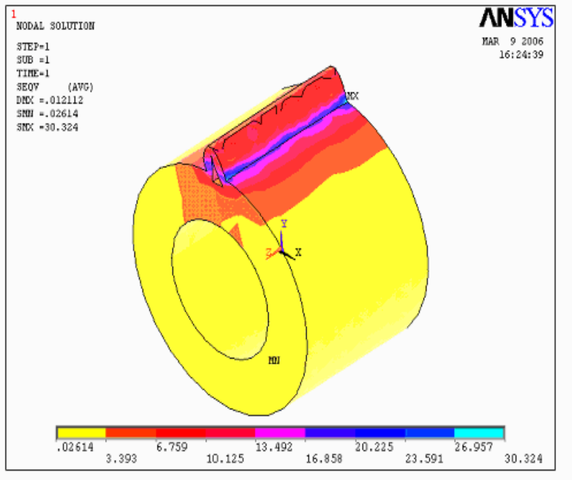
BASIC GEAR



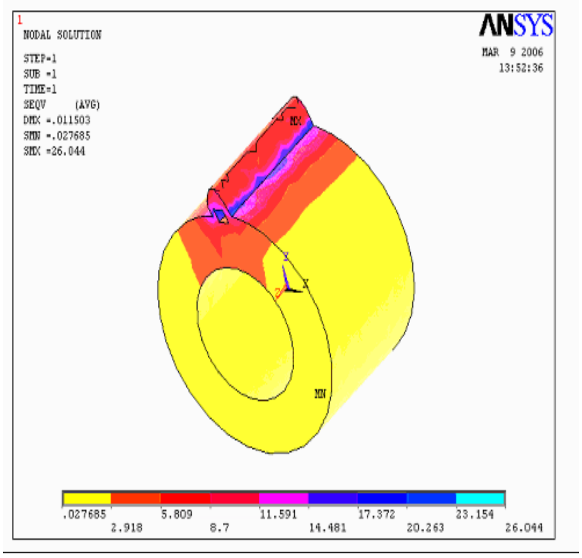
CIRCLE



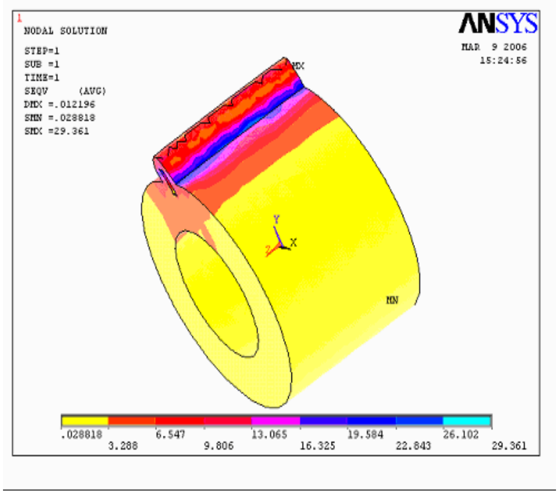
TRIANGLE



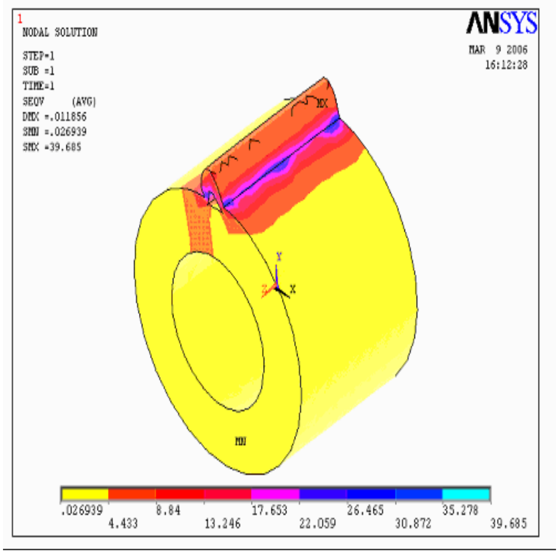
SQUARE



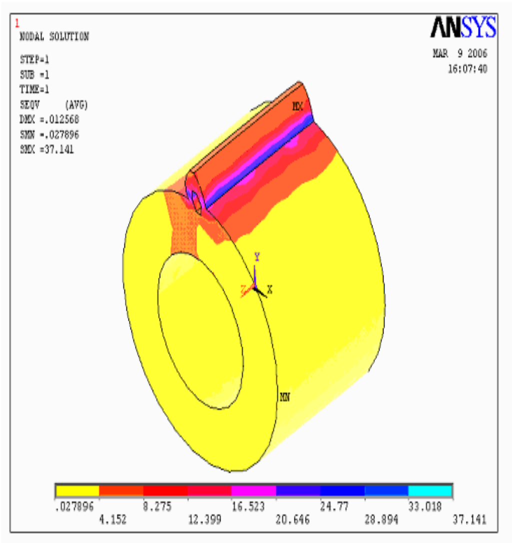
RECTANGLE



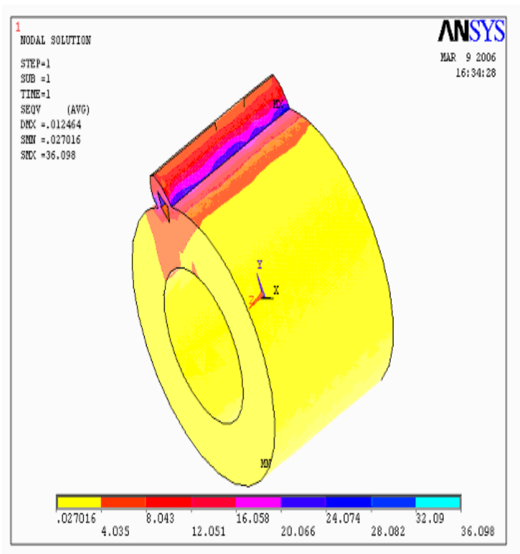
TRAPEZIUM



HEXAGON



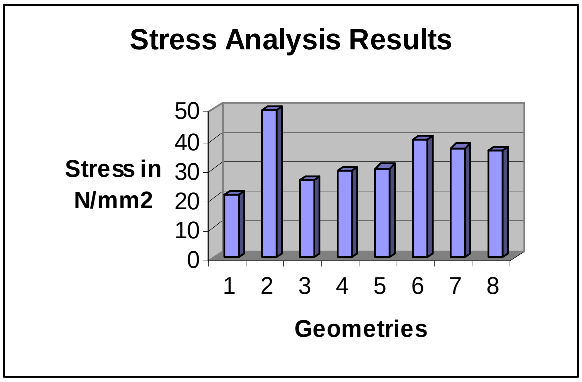
RHOMBUS



The consolidated results are,

Geometry Number	Geometry	Induced Stress In N/mm^2
1.	Basic Gear	21.11
2.	Circle	49.75
3.	Square	26.04
4.	Rectangle	29.36
5	Triangle	30.32
6	Trapezium	39.68
7	Hexagon	37.14
8	Rhombus	36.09

The Graphical representation of result is as follows

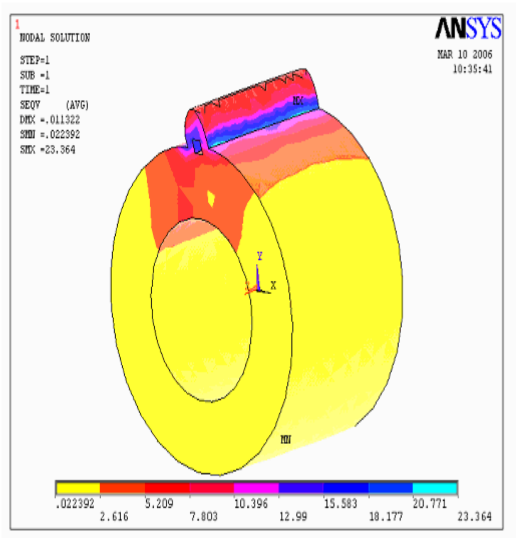


From the above Result analysis, it is clear that Square Cross Section doesn't give much induced stress and the value is closer to the Basic gear.

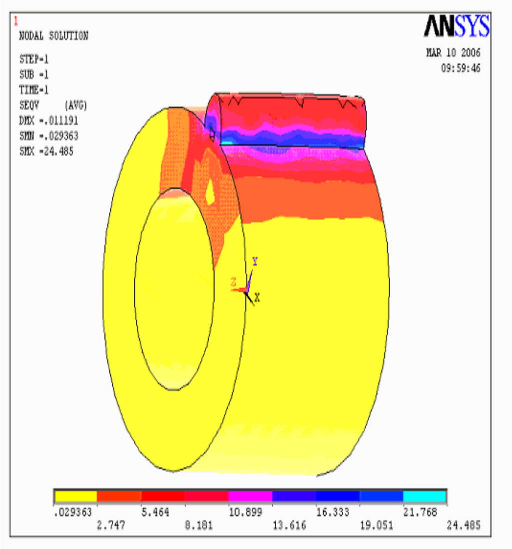
So, the Square cross section is optimized to do the further Case Study with respect to variation in Dimension of the Square.

The following dimensions of Squares are further analyzed 10*10, 15*15, 20*20 and 25*25. Already we have results for 20*20, hence the results of remaining three gears are as shown below,

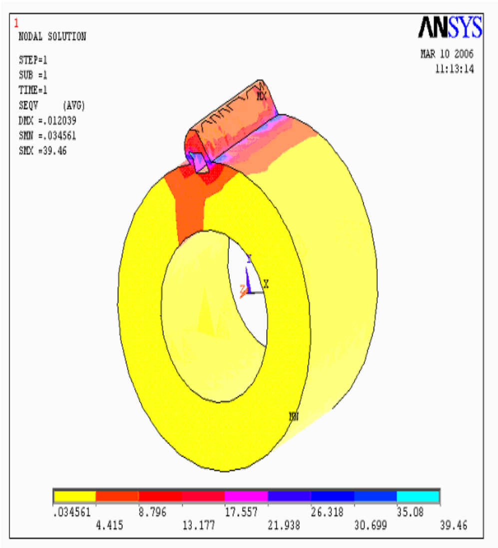
10*10 Square



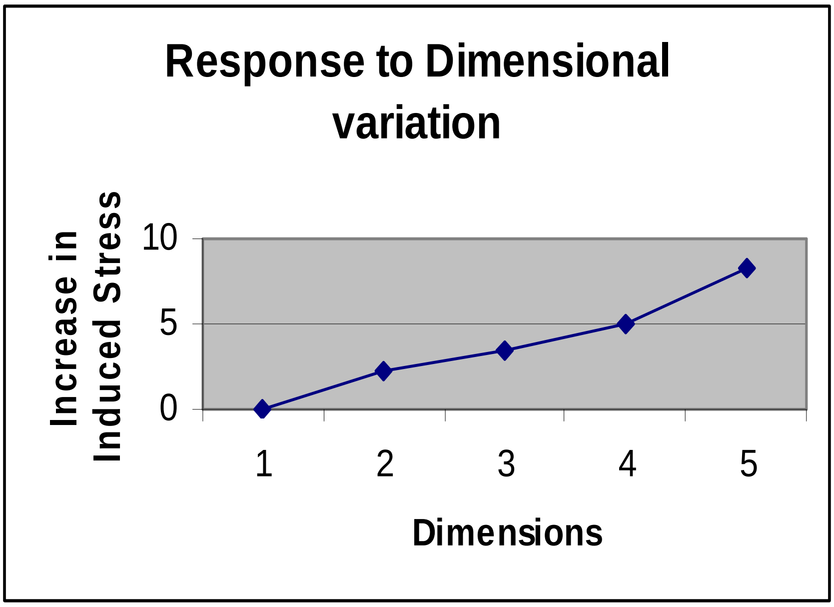
15*15 Square



25*25 Square



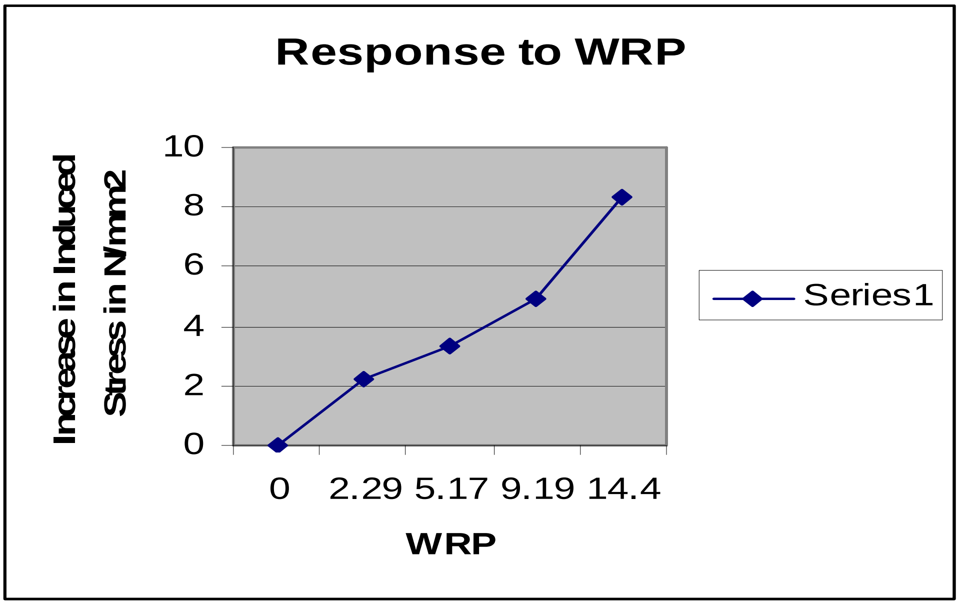
The Result Analysis is done as below



The values of Induced Stress observed are

S.No.	Dimensions	Induced Stress in N/mm^2	Increase in Stress ΔΩ
1.	Basic Gear (0*0)	21.11	NA
2.	10*10	23.364	2.254
3.	15*15	24.48	3.37
4.	20*20	26.044	4.934
5.	25*25	29.48	8.34

Response curve



5. WEIGHT REDUCTION PERCENTAGE (WRP)

WRP = (Change in volume/Volume of Basic Gear)*100

Volume of Basic gear = 228.34e5 mm^3

Volume of 10*10 gear = 223.09e5 mm^3

Volume of 15*15 gear = 216.53e5 mm^3

Volume of 20*20 gear = 207.34e5 mm^3

Volume of 25*25 gear = 195.53e5 mm^3

WRP_{10} =1-(223.09/228.34) = 2.29%

WRP_{15} =1-(216.53/228.34) = 5.17%

WRP_{20} =1-(207.34/228.34) = 9.19%
WRP_{25} =1-(195.53/228.34) =14.36%

RESULTS AND DISCUSSION

From the above study, it is clear that some of the geometry may suit for the optimal performance of the gear under the weight reduction. Square shape gives the optimal solution to induced stress. The various responses to WRP and dimensions on induced stress are analyzed. It is clear that when the weight reduces, induced stress increases. From this we can conclude that weight of the gear can be reduced by making appropriate hollow geometries without affecting the performance. This type of new gears may be employed in the systems where low weight is preferred such as Aerospace applications, etc. From this design, we can foresight that future gears may lose weight but with very good performance

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