Stress Analysis of Gearbox

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Abstract— This technical paper is on stress analysis of gearbox used in sugar industry. ANSYS is used for stress analysis. The main objective for carrying out this analysis was to improve the life of the gear. After the analysis of gears from existing gearbox the reason for failure was found. The reason for failure of the gear was due to wear of gear teeth edges. This is caused due to high stress concentration along the gear teeth edges. To relieve these stress concentration three modifications in the design of gears were done and after that again stress analysis of the modified gears carried out. It is observed that the stress relieved from edges and got concentrated to the edges of the holes provided at the roots of the teeth. The three design modifications were done as first, the edges of the gear teeth were tapered by an angle of 20, second, making groove in the gear wheel and third, making holes at the roots of the gear teeth. The expected increase in life of the gears of the gearbox would be three years.

1 Problem Definition

1.1 Definition of the Problem

Leading manufacturers of gearbox, which are used in various utensil and sugar mill machinery, faced the following problems

Interference
Surface Fatigue
Fracture

The gears fail when tooth stress exceeds the safe limit. Therefore, it is essential to determine the maximum stress that a gear tooth is subjected to, under a specified loading. Analysis of gears is carried out so that these can be prevented from failure. When failure occurs, they are expensive not only in terms of the cost of replacement or repair but also the cost associated with the downtime of the system of which they are a part.

1.2 Methodology Used

The modeling and stress analysis of the gearbox has been done in Pro-E and ANSYS respectively, taking various constraints and boundary conditions imposed by the company. The necessary design modifications have also been made to rectify the problems being faced by the firm.

1.3 Constraints

There were various constraints or restrictions that were imposed by the firm.

Material :- The gears were made of forged steel having specification EN24 as it is most economical.
Type of Gear :- Type of gear cannot be other than double helical gear.
Helix Angle and Pressure Angle :- The helix angle and pressure angle were fixed at 15^0. and 20^0. respectively.
Pitch Circle Diameter :- The pitch circle diameters of the gears mounted in the gearbox were fixed.
Number of Gears :- The number of gears mounted in the gearbox was fixed.

1.4 Inputs Given

Initial design or drawing of the gearbox was given.
The value of the horsepower of the motor driving the gearbox was also given.
The gears were made of forged steel having specification EN24.

Freedom provided for the gearbox
Design modifications in the gears can be done considering factors such as strength and stiffness.

1.5 Approach for the Problem

The following steps are used for solving of the problem :-
Step I : Modeling of all the parts of the gearbox correctly.
Step II : Assembly of all the parts of the gearbox.
Step III : Drawings of all the parts and assembly.
Step IV : Stress analysis (von mises) of all the gears mounted in the gearbox.
Step V : Design modifications to be made to reduce the stresses below the safe Or allowable stress limit.
For the above steps the CAE softwares Pro-E & ANSYS are to be used.

2 Stress Analysis Of Gearbox

2.1 Stress Analysis of Existing Gear Box

As discussed in the previous chapter, the following steps are used for problem solving.

2.2 Model Generation

Proper modeling of the parts is very important for getting accurate results of analysis. Creating the parts and its dimensioning scheme are important steps. The components of the gearbox were modeled in the part mode of Pro-E. The gearbox consists of the following parts :-

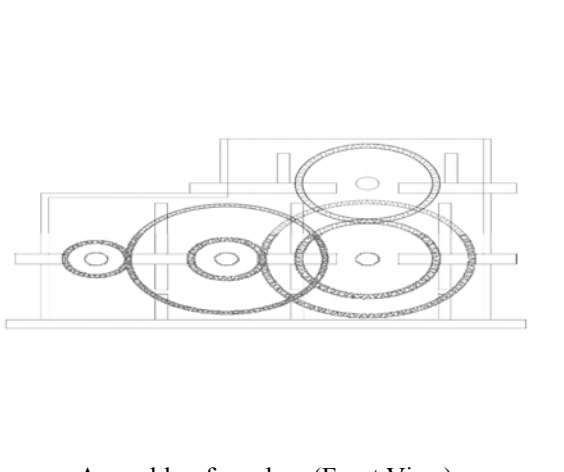
Double helical gears of dimensions as given in the table below :

Diameter (mm)	Number of teeth	Module (mm)
204	18	10
234	17	12
446	29	14
636	60	10
675	52	12

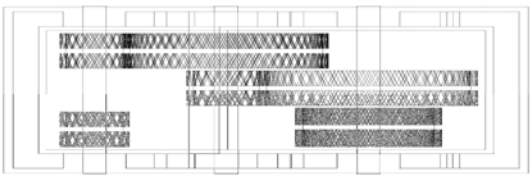
Shaft of diameter 75mm and of length 1100mm.
Gear housing of length 1674mm, breadth 1086mm and height 1141 mm.

2.3 Assembly of the Gear Box

The assembly of all the components of the gearbox was done in the assembly mode of Pro-E. The placement (or assembly) constraints were used to rigidly bind the components of the gearbox to their respective positions in the assembly



Assembly of gearbox (Front View)



Assembly of gearbox (Top View)

2.4 Introduction to Structural (Static) Analysis

With the widespread adoption of CAE approach to design, finite element analysis became integrated with the design and analysis procedure.
Structural (Static) analysis is used to analyze parts and assemblies to find :-

- Maximum Stresses
- Deformed Shapes (Deformation)

2.5 Structural (Static) Analysis Procedure

The analysis of a structure during its design process is accomplished by the solution of the partial differential equations that describe the given model. The structural (static) analysis involves the following procedure :-

- **Pre-Processing**
  It includes the description of the geometry or model, the physical
  Characteristics of the model and the mesh generation.
- **Solution**
  It involves the application of the finite element analysis.
- **Post-Processing**
  It includes the visualization and interpretation of the results of the solution.

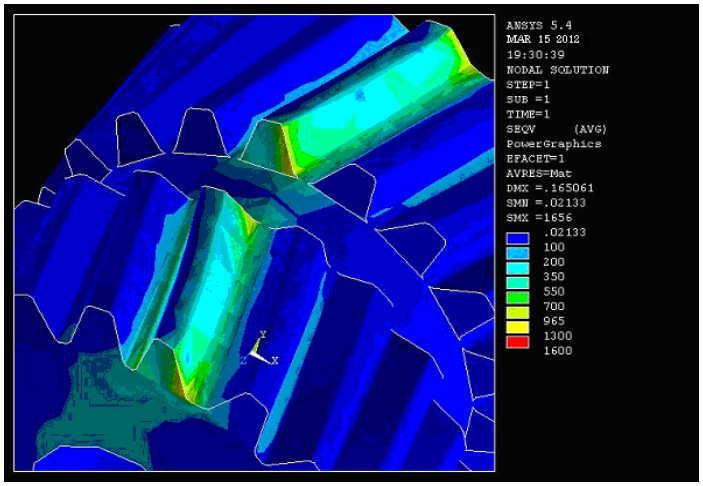
2.6 Design Modifications Undertaken

After extensive reviewing and studying the basic concepts of the stress, gears etc. some design modifications were made in order to reduce the stresses to the safe limit. The following design modifications are done in the existing gearbox :-

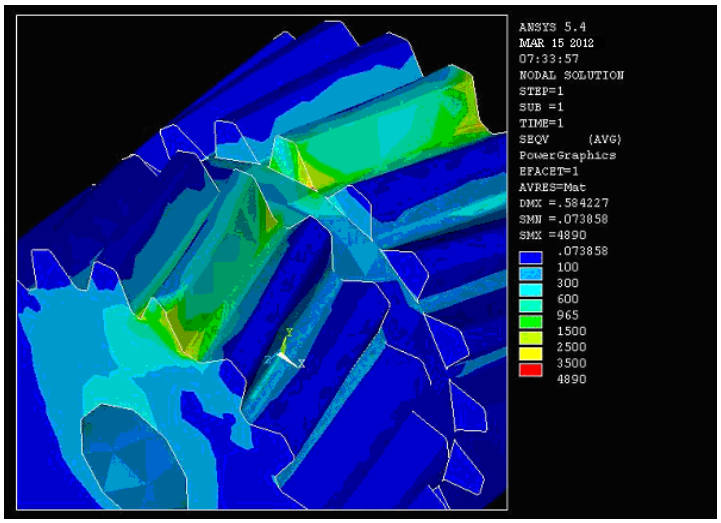
- The edges of the gear teeth were tapered by an angle of 20^0.

- Making a groove in the gear wheel.
- Making a hole at the roots of the gear teeth.

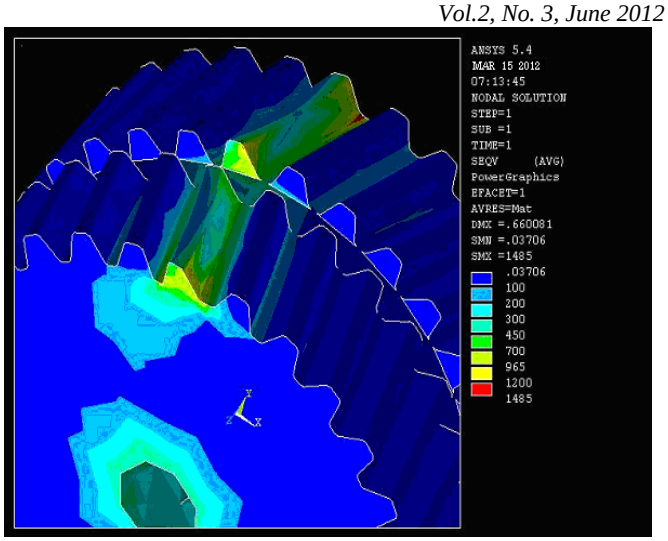
3 Following figures shows stress analysis of gears from existing gearbox



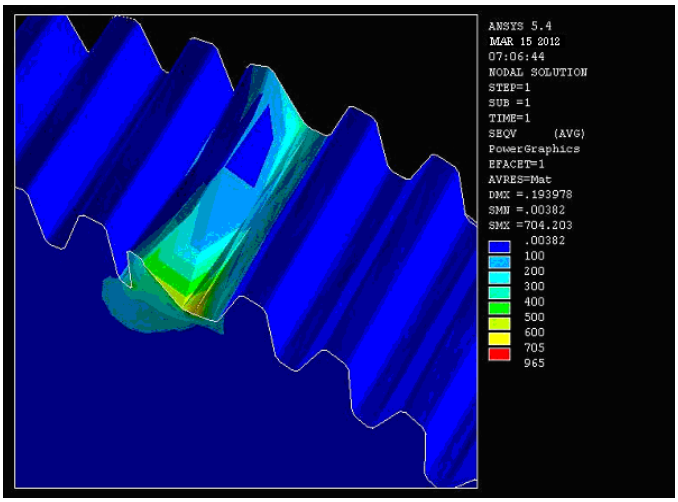
Stress analysis of double helical gear of diameter 204mm



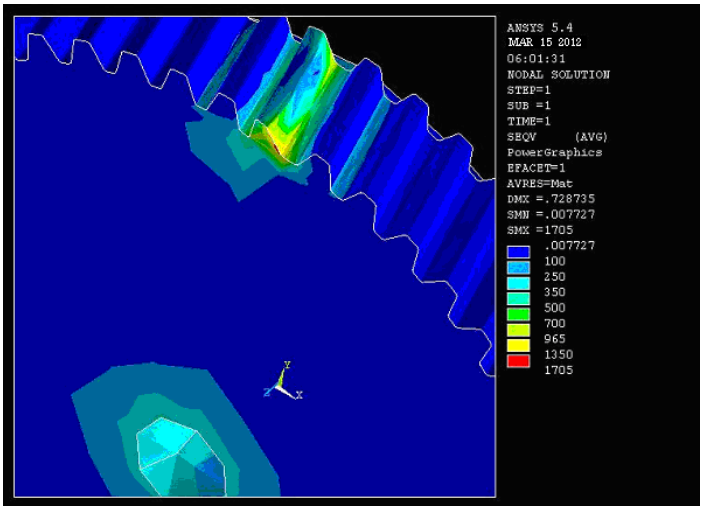
Stress analysis of double helical gear of diameter 234mm



Stress analysis of double helical gear of diameter 446mm

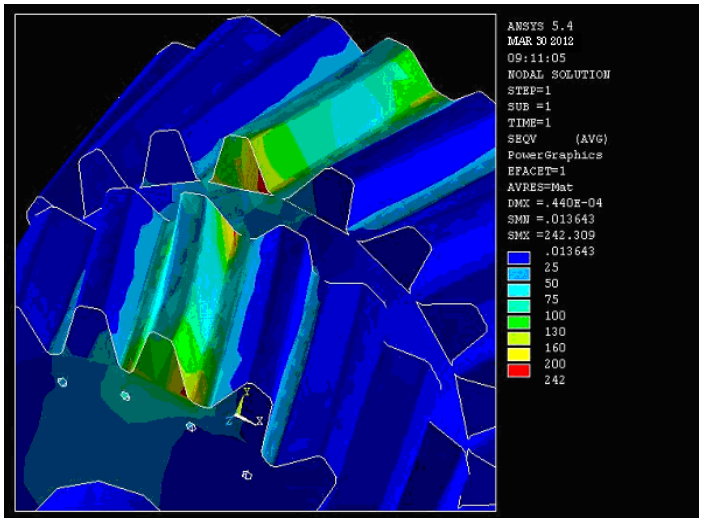


Stress analysis of double helical gear of diameter 636mm

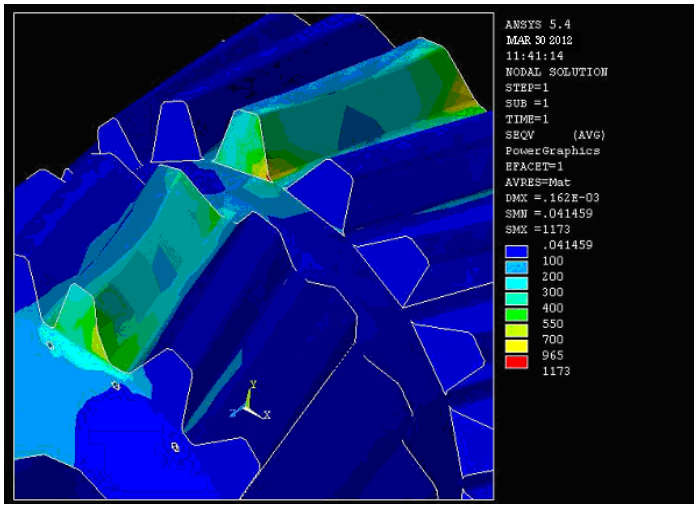


Stress analysis of double helical gear of diameter 675mm

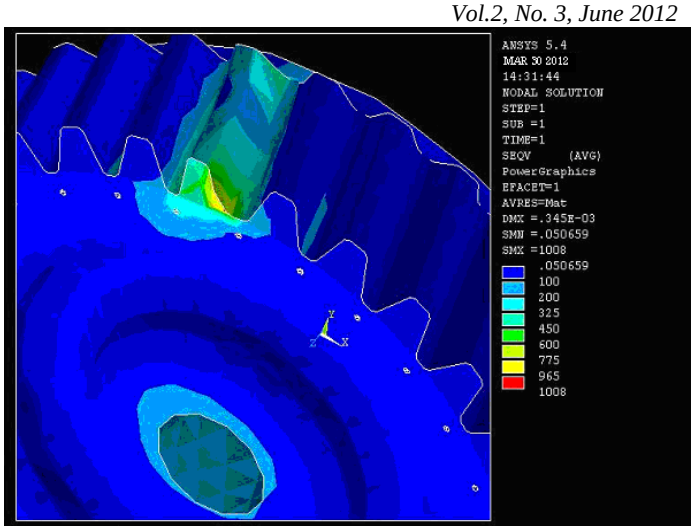
4 Following fig shows stress analysis of modified design of gears from gearbox



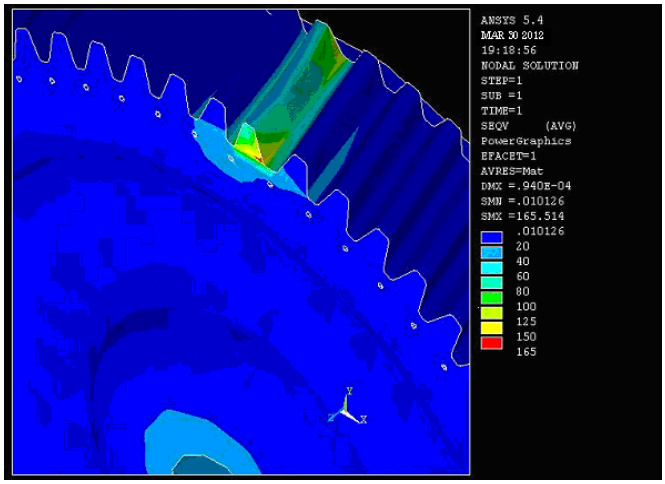
Stress analysis of modified double helical gear of diameter 204mm (Taper on edges and hole at the roots of the gear teeth)



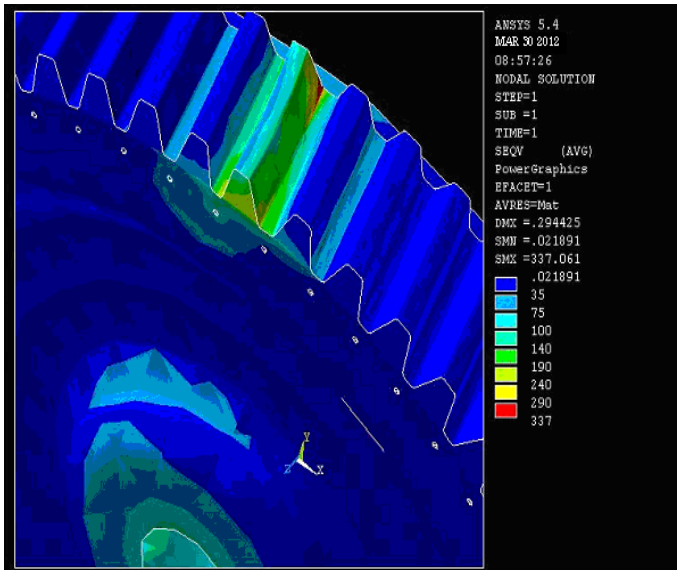
Stress analysis of modified double helical gear of diameter 234mm (Taper on edges and hole at the roots of the gear teeth)



Stress analysis of modified double helical gear of diameter 446mm (Taper on edges and hole at the roots of the gear teeth)



Stress analysis of modified double helical gear of diameter 636mm (Taper on edges and hole at the roots of the gear teeth)



Stress analysis of modified double helical gear of diameter 675mm (Taper on edges and hole at the roots of the gear teeth)

5 **Conclusions**

This paper discussed stresses induced in gears of existing gearbox which were not within permissible/safe limit After modifying the design of the existing gearbox, again the stress analysis was carried out and the results were found to be well within allowable/safe limit. It was further observed that the stresses induced on the gear tooth were reduced considerably by making hole at the root of the gear tooth.

6 Scope of Further Work

- For analyzing stresses induced in the gear teeth using finite element analysis only condition of static loading was applied. But actually the gears are subjected to dynamic loading condition, so there is an ample scope of further work if dynamic loading can also be applied for the analysis.
- As the hole at the root of the gear tooth acts as a stress reliever/reducer, hence its location and size can be optimized further. The number of holes to be made at the root of the gear tooth can also be optimized later on.
- Here only three modifications were used; some other design modifications can be incorporated to minimize the induced stresses on the gear tooth.

Appendix

Material Composition & Properties of Forged Steel (EN24)

The gears were made of forged steel of specification EN24 (Black Alloy Steel) of composition as given under :-

	C	Mn	Si	S	P	Cr	Mo	Ni
Min.	0.36	0.45	0.10	-	-	1.0	0.2	1.3
Max.	0.44	0.70	0.40	0.040	0.035	1.4	0.35	1.70

The material properties of EN24 are as under :-

Yield Strength (N/m2)	Ultimate Strength (N/m2)	Young's Modulus of Elasticity (N/m2)	Poission Ratio	Density (kg/m3)
$940 * 10^6$	$1100 * 10^6$	$205 * 10^9$	0.29	7850

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