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ANALYSIS OF CRACK DEFECT IN SPUR GEAR ON STRENGTH USING FINITE ELEMENT ANALYSIS

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ABSTRACT
Gears are the power transmission elements. Gears are used to transmit motion as well as power from one member to another. Any defect in gear will result in variation of power and torque. Gear teeth fails due to the static and the dynamic forces and the contact between the two meting gears causes the surface failures. To get the gear of more durability use of improved material, hardening of surface of gear, heat treatment and carburization, shot peening etc are performed over the gear. Present work deals with the analysis of effects of spur gear crack defect on strength with variation of gear parameters using Finite Element Analysis. Module, No of Teeth, and Pressure Angle considered for the analysis. For modeling and analysis CAD/CAM software Pro-Engineer Wildfire is used.

KEYWORDS: Spur Gear, Crack, Number of teeth, Module, Pressure Angle, and Pro-Engineer.

INTRODUCTION
In engineering and technology the term “gear” is defined as a machine element used to transmit motion and power between shafts by means of progressive engagement of projections called teeth. [1] A gear is said to be failed when it can no longer efficiently do the job for which it was designed. Causes of failure may range from excessive wear to catastrophic breakage. [2]

The finite element method is capable of providing the design/redesign of the gear information, but the time needed to create such a model is large. In order to reduce the modeling time, a preprocessor method that creates the geometry needed and Pro-Engineer provides this functionality. The finite element method is very often used to analyze the stresses in an elastic body with complicated geometry, such as a gear.

In this work the analysis is done to study the effects of Crack defect on strength of involute spur gear with variation of gear parameters. First the gears with no defects i.e. healthy gears are analyzed with variation of one parameter (like no. of teeth etc) and keeping all other parameters same is analysed. Then the same procedure is adapted with a gear with defect. The modeling of healthy and defective gear is done in Pro-Engineering software and then finite element analysis is carried out by taking the load at the highest point of the single tooth contact. The distortion of each healthy and defective gear with loading are compared.

LITERATURE SURVEY
On this topic many scientists are working and many of them find methods to increase the strength of the gear. Hui Li et al [3] used Hermitian wavelet to diagnose the gear localized crack fault. The simulative and experimental results show that Hermitian wavelet can extract the transients from strong noise signals and can effectively diagnose the localized gear fault. V. Spitas et al [4] did his work on spur gear teeth with circular instead of standard trochoidal root fillet is introduced and investigated numerically using FEA. M. Savage et al [5] has propose a bending strength model for internal spur gear teeth, this model assist design efforts for unequal addendum gears and gears of mixed materials. Durmus Gunay et al [6] investigate that, it is possible to improve load carrying of gears by selecting the proper addendum modification coefficient. Chia-Chang Liu et al [7] investigated the bearing contact characteristics of the gear pairs under varies assembly errors, and the contact ellipses .Dimensions of the

contact ellipse can be controlled by choosing appropriate tooth number of shapers. Christos A. Spitas et al [8] did his work on a new spur gear design, circular fillet replaces the normal trochoidal fillet, yielding large cross sectional at the tooth root and lower stress concentration and achieves increased tooth bending strength. A.O. Andrisano et al [9] proposed a CAD-FEM methodology for spur gears. The software generates the gear profiles from parameters describing the user rack. Particular attention is paid on simulating the enveloping process in the presence of protuberance and semi- topping in the cutting tool. Alexander L. Kapelevich et al [10] optimize the fillet profile which allows reducing the maximum bending stress in the gear tooth root area by 10-30%. It works equally well for both symmetric and asymmetric gear tooth profiles.

MODELLING OF GEAR

In total 25 numbers of gears are modelled in Pro/ENGINEER Wildfire [11], which are having the following parameters.

- Module –3 mm, 4 mm, 5 mm, 6 mm and 7 mm (Preferred Series)[1]
- No of Teeth – 15, 18, 20, 25 and 30[1]
- Pressure Angle - 14.5^0, 18^0, 20^0, and 24^0 [1]
- Defects – Crack,

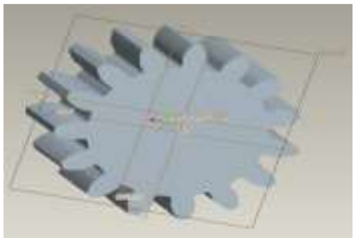
For modeling and analysis one parameter is varied and all other parameters are kept constant

The following steps are showing the procedure to model the gear of 15 numbers of teeth with the combination of the all above mentioned parameters in the Pro/ENGINEER Wildfire. Other set of gears are modelled in the similar way.

- Starting Pro/Engineer
- Preparing the sketch
- Defining Part Parameters
- Generation of Gear Blank
- Generation of Involutes Curve
- Cutting First Tooth Space
- Patterning the tooth Space
- Modeling the Gear with Circular fillet

These above mentioned steps referring from Mike Renfro [12] proposed a method for modeling of spur gear teeth in Pro/ Engineer Wildfire. Figure 1 showing the model of spur gear and figure 2 showing the model of spur gear with crack defect.

Figure:1



Gear model with no defect

Figure:2

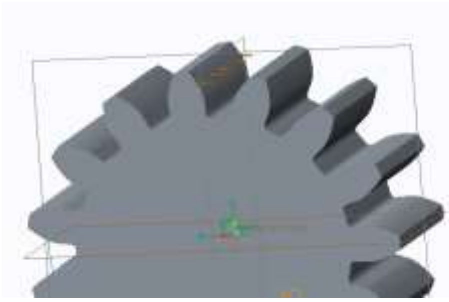
Gear model with crack defect

Other set of gears are modeled in the similar way.

STRUCTURAL ANALYSIS

The structural analysis of the spur gear tooth model is carried out using the finite element analysis in Pro/Mechanica which is an application of Pro/Engineer [11]. The following steps are showing the procedures to structural analysis the gear of 15 numbers of teeth in the Pro/Engineer, other set of gears are analysis in the similar way. The load applied at the highest point of single tooth contact as shown in the figure 3.

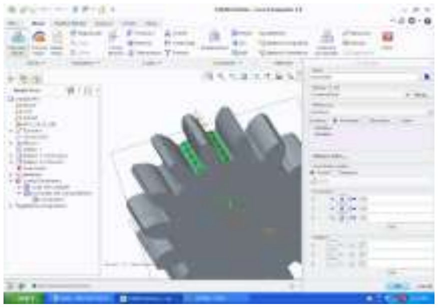
Figure:3



Loading at HPSTC with 100N

All degree of freedom of the surface both side of the tooth being constrained. Figure 4, is showing the displacement constrained.

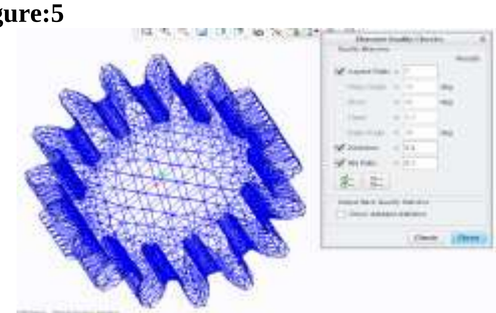
Figure:4



Displacement Constraint

At the Aspect Ratio of 7 the Mess is generated with tetrahedron nodes. Total 165818 element and 31359 nodes are created. Figure 5, is showing mess generation. Maximum element size of 5 mm is selected for the Mess control.

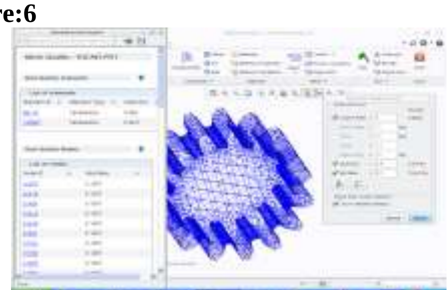
Figure:5



Mesh Generation

By applying the analysis over the surface which is facing the load we get distortion in the numeric as well as in the form of colour scheme. Figure 6, is showing the element quality check, the highlighted part which is the root of the gear is showing weak part of the gear it also describes the number of poorly shaped elements.

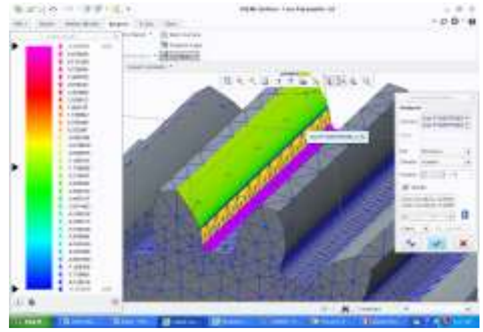
Figure:6



Element Quality Check

Figure 7, showing the finite element analysis in terms of the colour scheme with value of distortion produced due to loading.

Figure:7



Finite Element Analysis Results

RESULT AND DISCUSSION

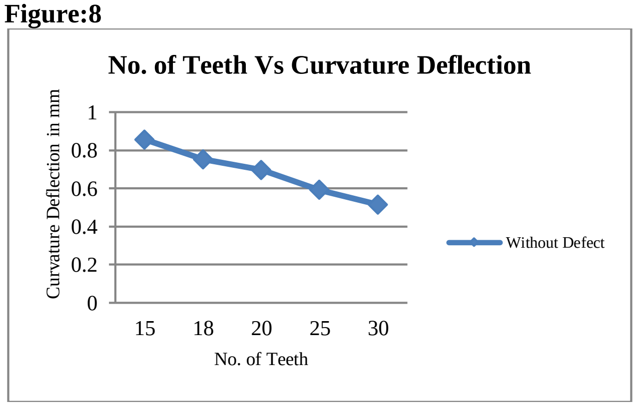
Case (i) - In the first case curvature deflection is shown in the form of value for healthy gear, when number of teeth increases. These values are showing in table 1.

Table 1(Healthy Gear)

S.No.	No. of teeth	Curvature Deflection (mm)
1	15	0.8553
2	18	0.7521
3	20	0.6972
4	25	0.5913
5	30	0.5146

Figure 8 is representing the graph between the number of teeth and Curvature Deflection for the healthy gear.

Figure:8



Graph No. of teeth Vs Curvature Deflection for Healthy Gear

Now curvature deflection is shown in the form of value for defective gear like Crack, when number of teeth increases. These values are showing in table 2.

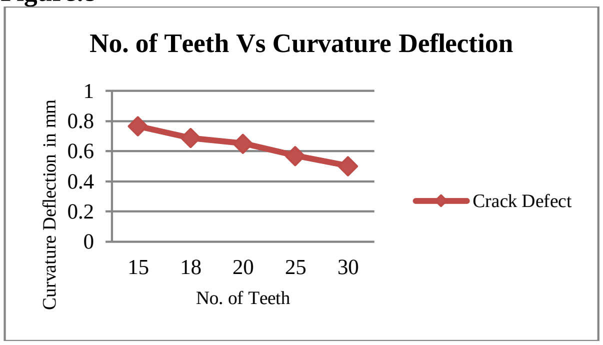
Table 2(Crack Defect)

S.No.	No. of teeth	Curvature Deflection (mm)

1	15	0.7652
2	18	0.6886
3	20	0.6502
4	25	0.5688
5	30	0.5016

Figure 9 is representing the graph between the number of teeth and Curvature Deflection for the defective gear.

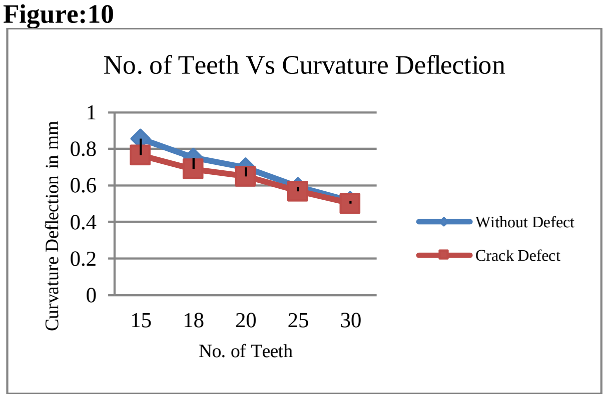
Figure:9



Graph No. of teeth Vs Curvature Deflection for Crack Defect

Graph shown in the figure 10 in Case I, the effect of healthy and defective gears of different numbers of teeth is investigated; it shows the distortion produced in the gear of 15, 18, 20, 25, and 30 number of teeth.

Figure:10



Graph No. of teeth Vs Curvature Deflection

Maximum deflection is shown by the gear having no defect i.e. without defect and minimum deflection is produced in the defective gear i.e. in the gear of crack defect when number of teeth increases.

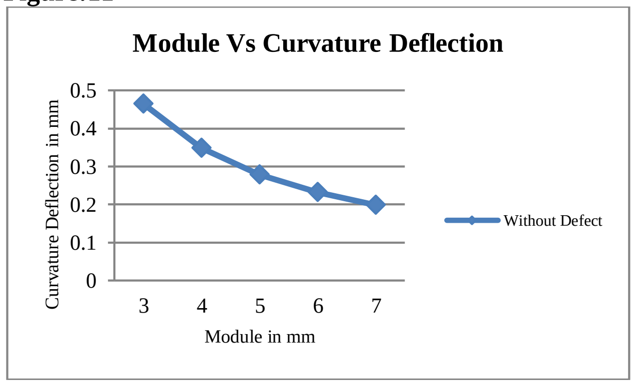
Case (ii) - In the second case curvature deflection is shown in the form of value for healthy gear, when module increases. These values are showing in table 3.

Table 3(Healthy Gear)

S.No.	Module (mm)	Curvature Deflection (mm)
1	3	0.4648
2	4	0.3486
3	5	0.2789
4	6	0.2324
5	7	0.1992

Figure 11 is representing the graph between the Module and Curvature Deflection for the healthy gear.

Figure:11



Graph Module V/s Curvature Deflection for Healthy Gear

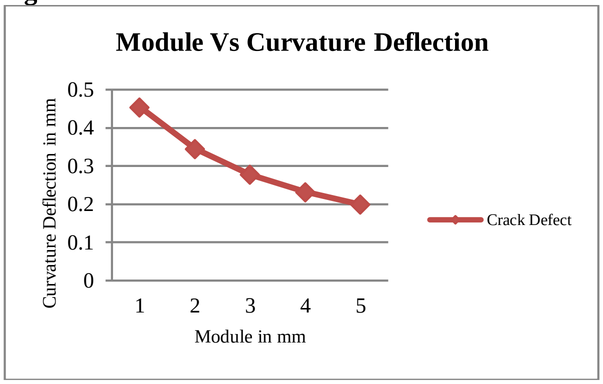
Now curvature deflection is shown in the form of value for defective gear like Crack, when module increases. These values are showing in table 4.

Table 4 (Crack Defect)

S.No.	Module (mm)	Curvature Deflection (mm)
1	3	0.454
2	4	0.3451
3	5	0.2776
4	6	0.2319
5	7	0.1991

Figure 12 is representing the graph between the number of teeth and Curvature Deflection for the defective gear.

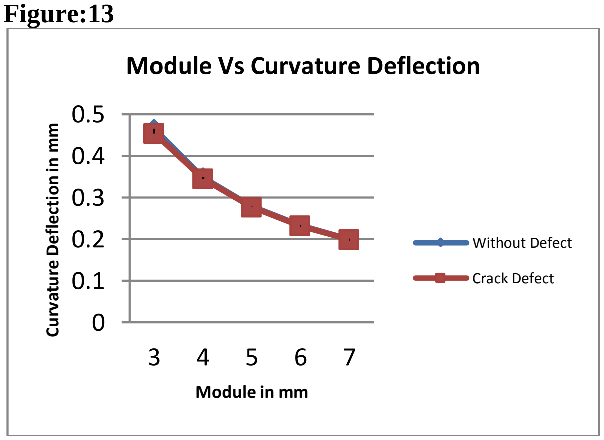
Figure: 12



Graph Module V/s Curvature Deflection for Crack Defect

Graph shown in the figure 13 in Case II, the effect of healthy and defective gears of different Module is investigated; it shows the distortion produced in the gear module of 3mm, 4mm, 5mm, 6mm, and 7mm.

Figure:13



Graph Module Vs Curvature Deflection

Maximum deflection is shown by the gear having no defect i.e. without defect and minimum deflection is produced in the defective gear i.e. in the gear of Crack defect when module increases.

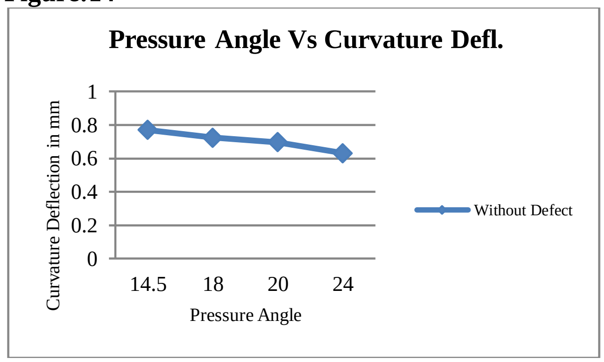
Case (iii) - In the third case curvature deflection is shown in the form of value for healthy gear, when Pressure Angle increases. These values are showing in table 5.

Table 5 (Healthy Gear)

S.No.	Pressure Angle	Curvature Deflection (mm)
1	14.5	0.7702
2	18	0.7239
3	20	0.6972
4	24	0.6322

Figure 14 is representing the graph between the Pressure Angle and Curvature Deflection for the healthy gear.

Figure:14



Graph Pressure Angle V/s Curvature Deflection for Healthy Gear

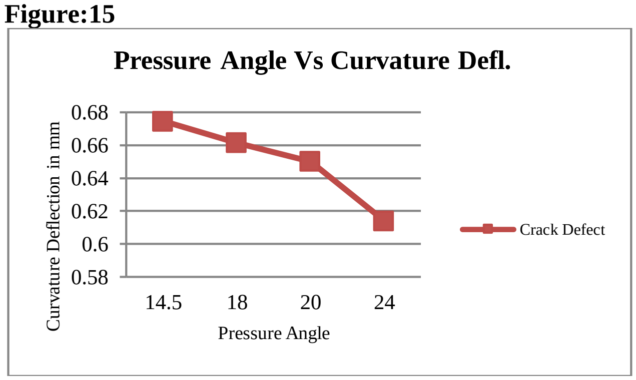
Now curvature deflection is shown in the form of value for defective gear like Crack, when Pressure Angle increases. These values are showing in table 10

Table 6 (Crack Defect)

S.No.	Pressure Angle	Curvature Deflection (mm)
1	14.5	0.6745
2	18	0.6615
3	20	0.6502
4	24	0.614

Figure 15 is representing the graph between the Pressure Angle and Curvature Deflection for the defective gear.

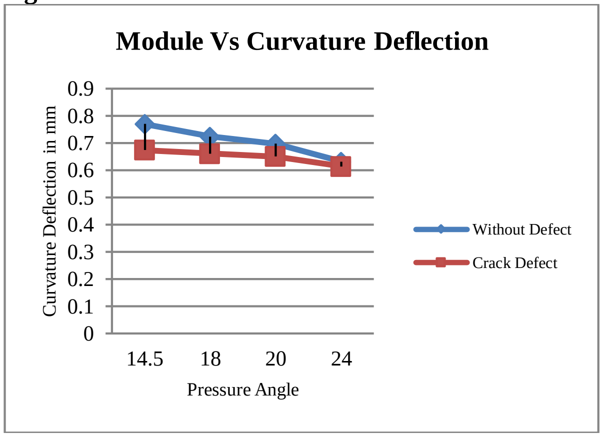
Figure:15



Graph Pressure Angle V/s Curvature Deflection for Crack Defect

Graph shown in the figure 16 in Case III, the effect is investigated of healthy and defective gears when different Pressure Angle; it shows the distortion produced in the gear Pressure angle of 14.5^0, 18^0, 20^0, and 24^0.

Figure:16



Graph Pressure Angle Vs Curvature Deflection

Maximum deflection is shown by the gear having no defect i.e. without defect and minimum deflection is produced in the defective gear i.e. in the gear of crack defect when pressure angle increases.

CONCLUSION

The effect on the strength of involute spur gear by crack defect was investigated. Gear of different parameters and but having one parameter is varied and all other parameters are kept constant was modeled and distortion produced in the curvature due to loading at the highest point of single tooth contact was analysed by finite element analysis.

1. From the analysis it is concluded that, as number of teeth increases from 15 to 30 in healthy gear curvature deflection decreases and similarly in defective gears curvature deflection decreases it is shown in figure 10. Hence we can say that when there is crack defect in small gear then its strength will be very less compare to healthy gear but if there is crack defect in big gear its strength will not be much lesser compare to healthy gear.

2. As module increases from 3mm to 7mm in healthy gear curvature deflection decreases and similarly in defective gears curvature deflection decreases it is shown in figure 13. Hence we can say that when there is crack defect in gear having less module then its strength will be very less compare to healthy gear but if there is crack defect in gear having high module its strength will not be much lesser compare to healthy gear.

3. As pressure angle increases from 14.5^0 to 24^0 in healthy gear curvature deflection decreases and similarly in defective gears curvature deflection decreases it is shown in figure 16. Hence we can say that when there is crack defect in gear having less Pressure angle then its strength will be very less compare to healthy gear but if there is crack defect in gear having high Pressure angle its strength will not be much lesser compare to healthy gear.

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