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FINITE ELEMENT ANALYSIS OF A SPUR GEAR TOOTH USING SOLIDWORKS SIMULATION AND STRESS REDUCTION BY STRESS RELIEF HOLE

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ABSTRACT

Gears generally fail when the working stress exceeds the maximum permissible stress. Number of studies has been done by various authors to analyse the gear for stresses. Gears have been analysed for different points of contact on thetooth profile and the corresponding points of contact on the pinion. In this study the technology of gears is presented along with the various types of failures that gears have. The causes of these failures are studied and one type of stress related failure due to fatigue failure of a gear tooth due to stress concentration is detailed. This work presents the stress redistribution by introdusing the stress relieving features in the stressed zone to the reduction of root fillet stress in spur gear. In this work circular stress relieving features are used and better results are obtained. A finite element model with a segment of three teeth is considered for analysis and stress relieving features of various diameters are introdused on gear teeth.Analysis revealed that circular stress relieving feature at specific locations are benefecial.

Index Terms:spur gear, FEA, stress redistrbution

1.INTRODUCTION

A gear is a component within a transmission device that transmits rotational force to another gear or device.The objective of the gear drive is to transmit power with comparatively smaller dimensions, light weight,less stress,runs reasonably free of noise and vibration with least manufacturing and maintenance cost. In 1992 Srinivassalu [1] experimented by placing the holes in relatively low stress neutral axis of the bending of the gear tooth. In 1997 ,Fredette and M. Brown [2] focussed their research work on “Gear Stress Reduction Using Internal Stress Relief Feature”. Tsai M. [2] focussed their research work to design the stronger tooth profiles. Legge G. and Herring D.H. [4] proposed improved methods on heat treatment. Spitas V.A and Alexander L.K.[5] redesigned novel gear root fillets to improve the strength of the gear.S. Sankar and M. Sundar Raj [6] investigated the profile modification for increasing the tooth strength in spur gear using CAD. Daniela Ristic [7] investigated numerical stress concentration analysis of a driven gear tooth root with two fillet radius.In 1990 the work of Dippery [8] showed that stress concentration reduction is possible in generic shapes. Ashwini Joshi, Vijay Kumar Karma [9] investigated the effect on strength of involute spur gear by changing the fillet radius using FEA. In 2007 M.S. Hebbal, V.B. Math, C.M. Veerendrakumar, S.B.Kerur [10] proposed an approach to the redistribution of Root Fillet Stress in Spur gear.The theory that the maximum tensile stress can be reduced by placement of holes in the stressed area is based on the idea that stress will be relieved and displaced away from the critical area.In this work the circular stress relieving features are used and effect of change in diameter and change in distance from root circle also investigated.

2.ANALYSIS

A finite element model with a segment of three teeth is considered for analysis. A point load of 200 N of gear width is applied at the tip of the gear. The boundary conditions used are similar to the one proposed by Von Eiff et al. [13].A program is developed in SolidWorks Simulation to automate the process of geometry creation, meshing, applying boundary conditions and displaying the results.The program reads an IGES file out from the SolidWorks for geometry of gear teeth, the location and size of the stress relieving features. A standard spur gear with module 2.5mm, number of teeth 47, pressure angle 20 degrees, radius factor 0.3 is considered for analysis. The gear material having Ultimate Tensile stress equal to241.3 N/mm² and Poisson's ratio equal to 0.26 is considered for analysis.The FEA results of root fillet stress (without holes) are compared with the stress calculated using the gear rating calculation procedure specified in AGMA standards.

Fig.1 shows the maximum principal stress without any stress relieving features.

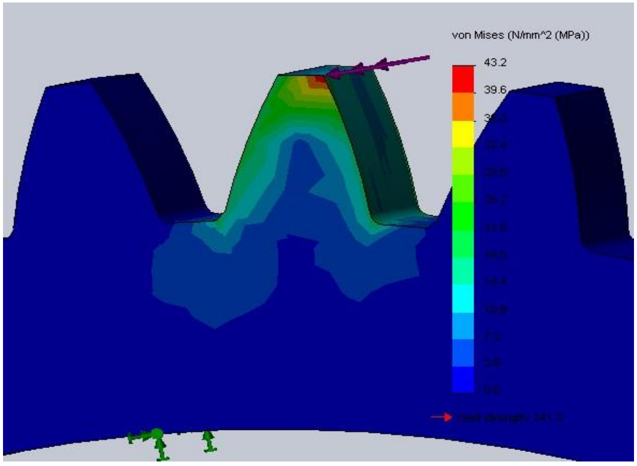

Figure.1. Max. principal stress without stress relieving features is 43.2 N/mm²(Mpa)

Now by creating the hole of different diameters below the root circle diameter at different locations between two teeth we find the different results after the stress analysis. The results are given below:

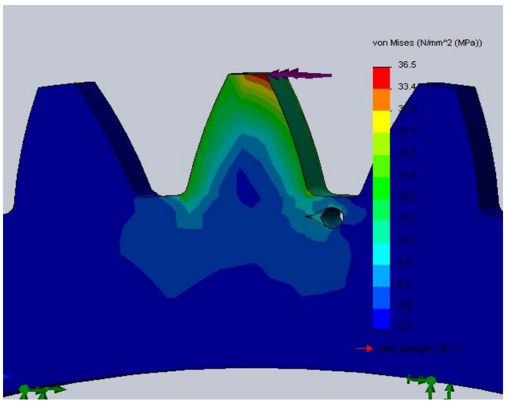

Fig.2.

Stress value 36.5 MPa,Hole Diameter 1.0mm.

Distance from root circle is 1.0 mm.

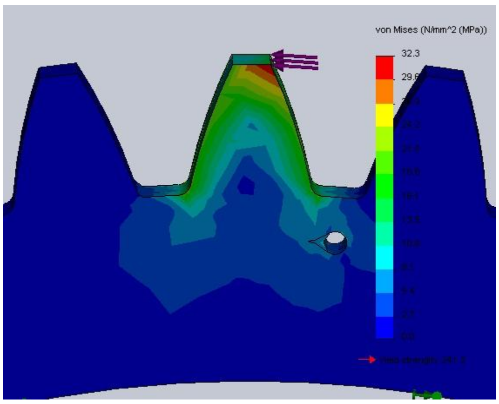

Fig.3.

Stress value 32.3 Mpa,Hole Diameter 1.0mm.

Distance from root circle is 2.0 mm.

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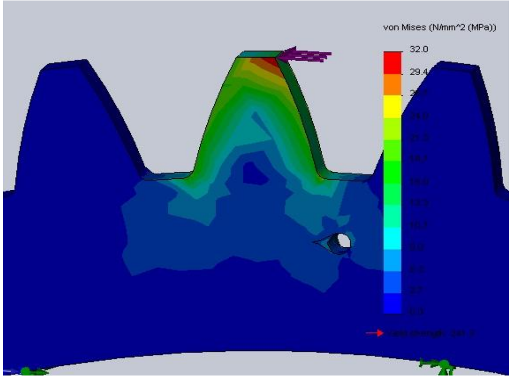

Fig.4.

Stress value 32.0 MPa,Hole Diameter 1.0mm.

Distance from root circle is 3.0 mm.

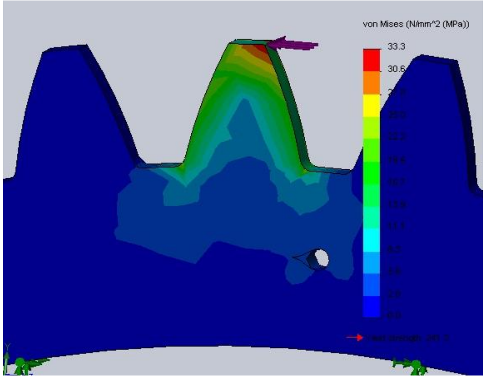

Fig.5.

Stress value 33.3 Mpa,Hole Diameter 1.0mm.

Distance from root circle is 4.0 mm.

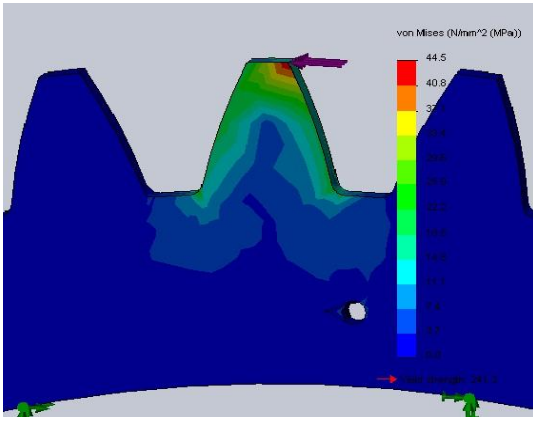

Fig.6.

Stress value 44.5 MPa,Hole Diameter 1.0mm.

Distance from root circle is 5.0 mm.

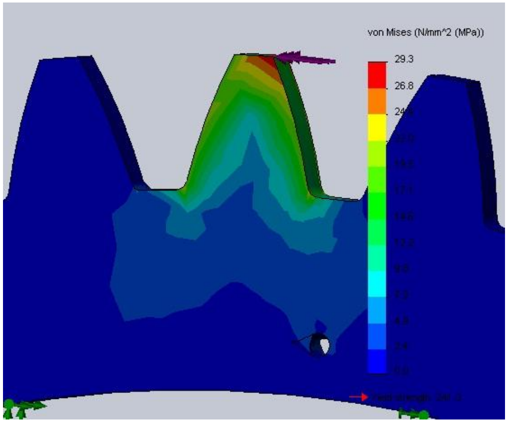

Fig.7.

Stress value 29.3 Mpa,Hole Diameter 1.0mm.

Distance from root circle is 6.0 mm.

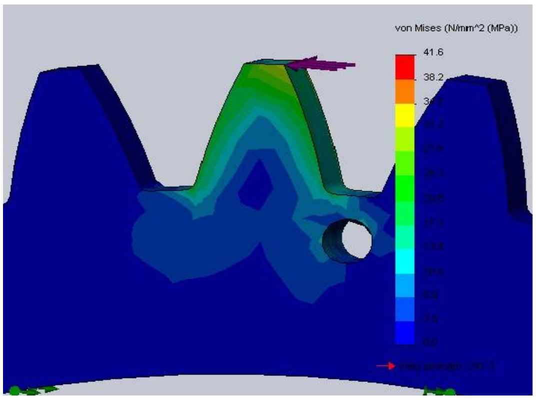

Fig.8.

Stress value 41.6 MPa,Hole Diameter 2.0mm.

Distance from root circle is 2.0 mm.

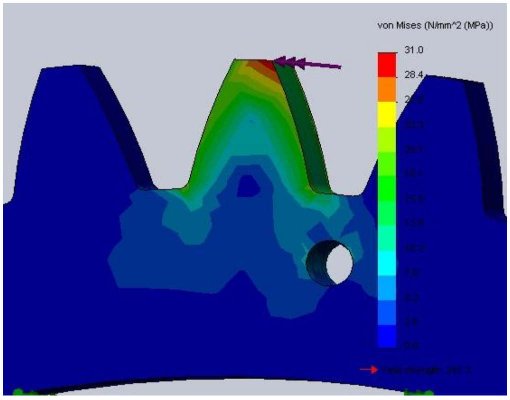

Fig.9.

Stress value 31.0 Mpa,Hole Diameter 2.0mm.

Distance from root circle is 3.0 mm.

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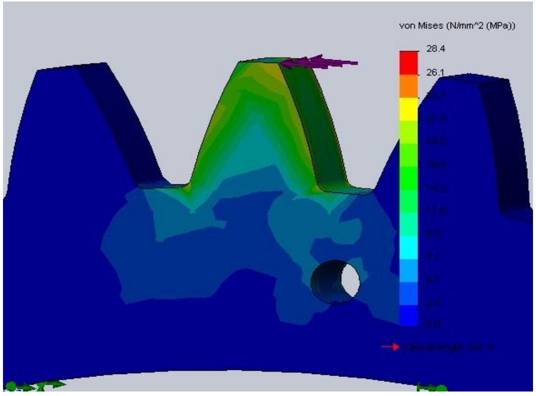

Fig.10.

Stress value 28.4 MPa,Hole Diameter 2.0mm.

Distance from root circle is 4.0 mm.

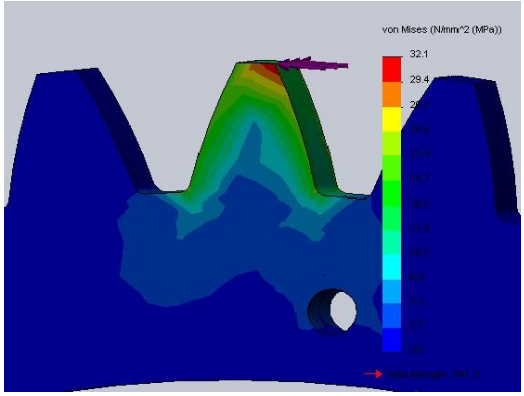

Fig.11.

Stress value 32.1 Mpa,Hole Diameter 2.0mm.

Distance from root circle is 5.0 mm.

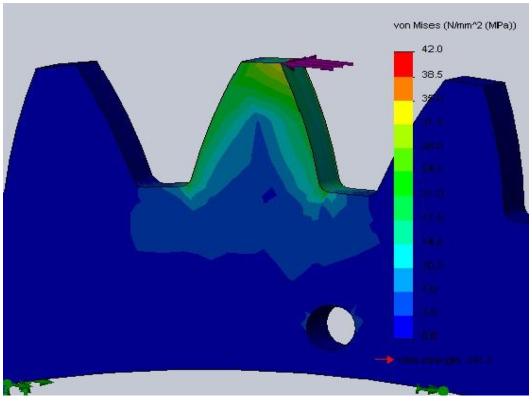

Fig.12.

Stress value 42.0 MPa,Hole Diameter 2.0mm.

Distance from root circle is 6.0 mm.

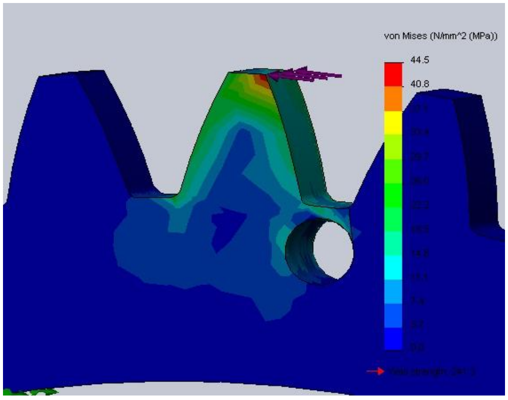

Fig.13.

Stress value 44.5 Mpa,Hole Diameter 3.0mm.

Distance from root circle is 2.0 mm.

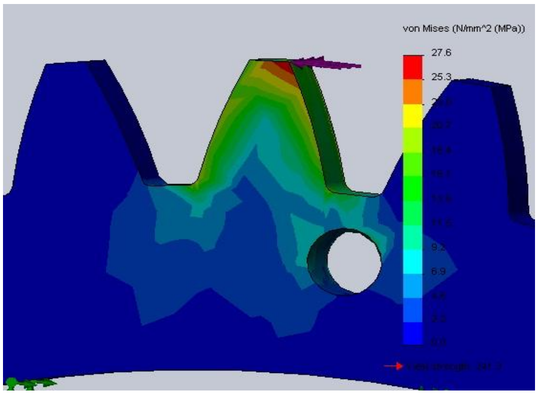

Fig.14.

Stress value 27.6 MPa,Hole Diameter 3.0mm.

Distance from root circle is 3.0 mm.

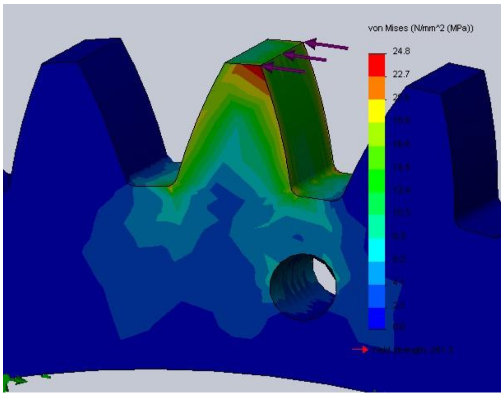

Fig.15.

Stress value 24.8 Mpa,Hole Diameter 3.0mm.

Distance from root circle is 4.0 mm.

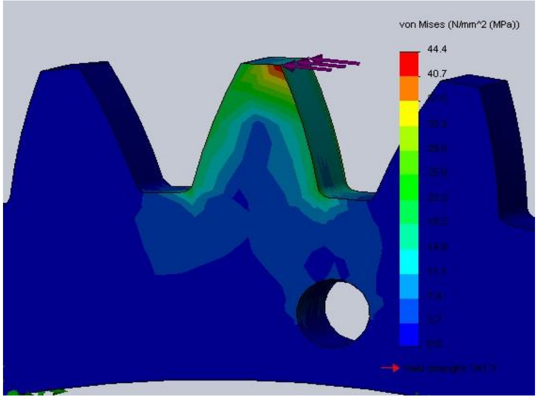

Fig.16.

Stress value 44.5 MPa,Hole Diameter 3.0mm.

Distance from root circle is 5.0 mm.

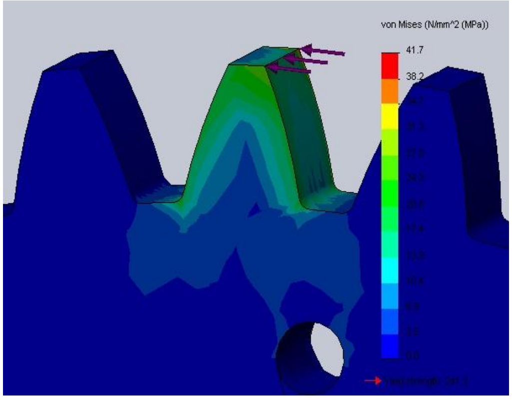

Fig.17.

Stress value 41.7 Mpa,Hole Diameter 3.0mm.

Distance from root circle is 6.0 mm.

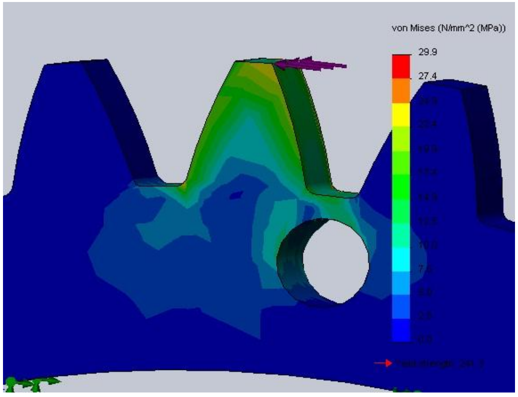

Fig.18.

Stress value 29.9 MPa,Hole Diameter 4.0mm.

Distance from root circle is 3.0 mm.

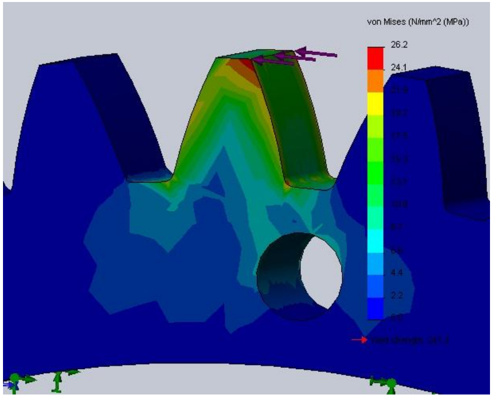

Fig.19.

Stress value 26.2 Mpa,Hole Diameter 4.0mm.

Distance from root circle is 4.0 mm.

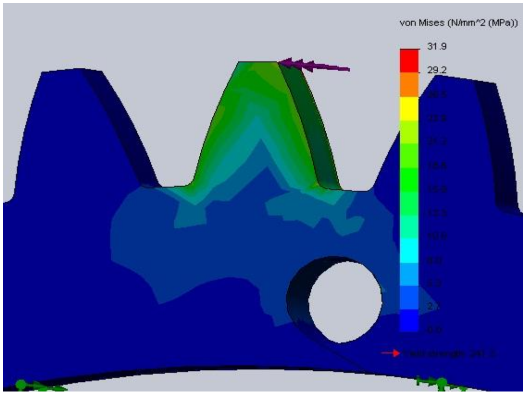

Fig.20.

Stress value 31.9 MPa,Hole Diameter 4.0mm.

Distance from root circle is 5.0 mm.

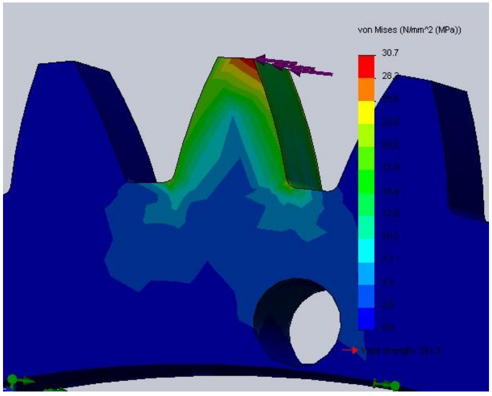

Fig.21.

Stress value 30.7 Mpa,Hole Diameter 4.0mm.

Distance from root circle is 6.0 mm.

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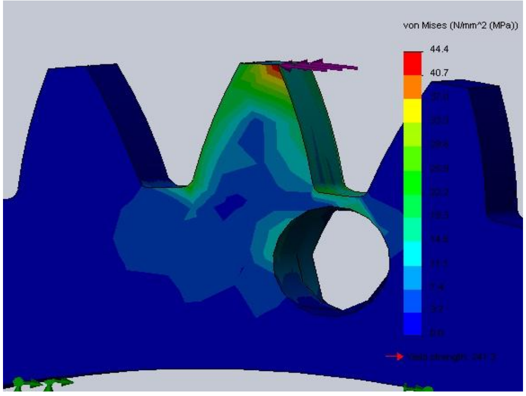

Fig.22.

Stress value 44.4 MPa,Hole Diameter 5.0mm.

Distance from root circle is 3.0 mm.

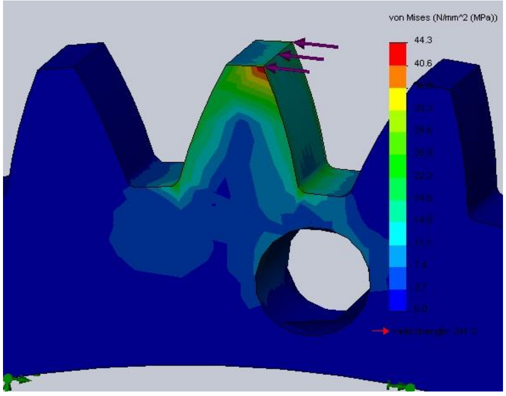

Fig.23.

Stress value 44.3 Mpa,Hole Diameter 5.0mm.

Distance from root circle is 4.0 mm.

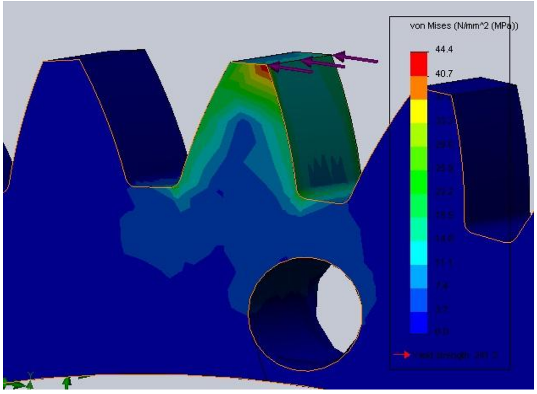

Fig.24.

Stress value 44.4 MPa,Hole Diameter 5.0mm.

Distance from root circle is 5.0 mm.

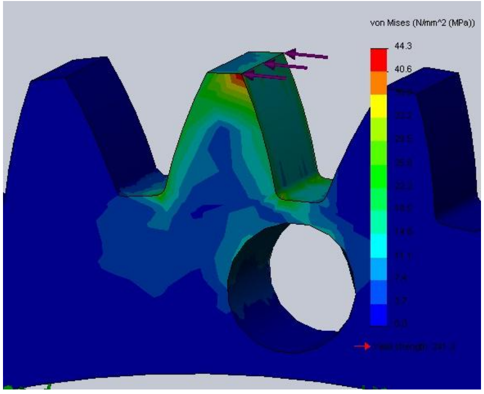

Fig.25.

Stress value 44.3 Mpa,Hole Diameter 6.0mm.

Distance from root circle is 4.0 mm.

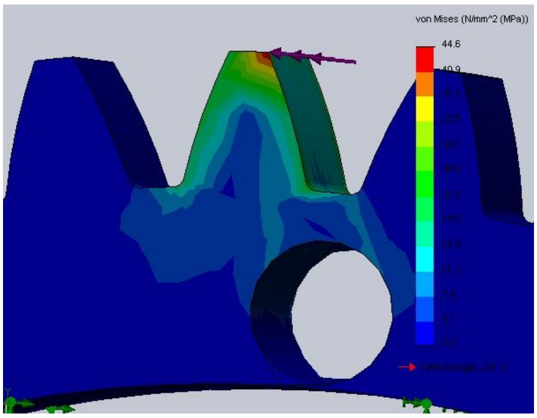

Fig.26. Stress value 44.6 Mpa, Hole Diameter 6.0mm.,Distance from root circle is 5.0 mm.

3.RESULTS AND DISCUSSIONS

Max. principal stress without stress relieving features is 43.2 N/mm²(Mpa). Max. principal stress with stress relieving features is given below in the table by creating circular stress relief feature at different locations:

S.No.	Hole Diameter in mm.	Stress values in Mpa					
		Hole Distance from root circle in mm.					
		1	2	3	4	5	6
1.	**1**	36.5	32.3	32.0	33.3	44.5	29.3
2.	**2**	X	41.6	31.0	28.4	32.1`	42.0
3.	**3**	X	44.5	27.6	**24.8**	44.4	41.7
4.	**4**	X	X	29.9	26.2	31.9	30.7
5.	**5**	X	X	44.4	44.3	44.4	X
6.	**6**	X	X	X	44.3	44.6	X

It is found that the maximum principal stress at root fillet is 43.2 Mpa without any stress relieving features (Fig.1). Various cases are considered for analysis choosing different values of hole position and diameter. Analysis reveals that the case with a circular hole having 3mm. diameter and 4mm. distance from root circle shows the greater benefit in comparison with other cases by reducing stress at root fillet to 24.8 Mpa(Fig.15). As the location of stress relieving feature approaches the high stress gradient zone up to a certain value, the results are found to be beneficial. Later on the benefit to the change in size of the stress relieving feature. A careful selection of more than one location for introducing stress relieving feature is more beneficial than choosing only one.

4.CONCLUSIONS

As per analysis stress reduction by means of introducing stress reliving feature is possible. The redistribution is highly sensitive to the change in size of the stress relieving feature. A careful selection of more than one location for introducing stress relieving feature is more beneficial than choosing only one.Stress reductions by means of introducing circular stress reliving features are found to be better.The circular stress relief feature have better control over changing the stress redistribution pattern. The introduction of a circular hole below the root circle diameter between two teeth reduces the stress levels by a very high percentage about 42%.So by optimizing the diameter and position of the stress relief hole we can reduce the stress value in a gear tooth by a considerable amount without affecting the functioning of the gear.

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