Structural Analysis to Study the Effect of Root Fillet Radius on Mechanical Properties of a Helical Gear Used in Dry Screw Vacuum Pump

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Abstract - Helical gears have been widely used in the dry screw vacuum Pump industry. This paper described FEA software Ansys Mechanical to study the effect of root fillet radius on mechanical properties of a helical gear. When, vacuum pumps are used for long hours, even light loads could cause failure. Hence, even a small enhancement in the life of gear due to change in root fillet radius could prove to be beneficial for reliable operation of dry screw vacuum pump.

Key Words: **Dry Screw Vacuum Pump, Helical Gear, FEA, Structural Analysis, Axial Loads, Stress**

1.INTRODUCTION

Dry screw vacuum pump is widely used in manufacturing, pharmaceutical, nuclear research and petrochemical industries [1]. The major advantage of dry screw vacuum pump is it generates no oil and gas during operation which increases its reliability. One of the major components of dry screw vacuum pumps is helical gears which are used to synchronously rotate the two extruders in the vacuum pump.

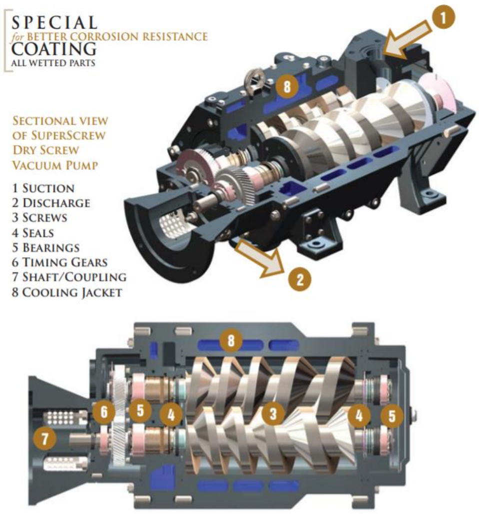

Fig-1: Helical gear assembly in Dry Screw Vacuum Pump Assembly [1]

One of the primary reasons why helical gears are used instead of spur gears because of its durability. These pumps need to operate in harsh conditions for long duration of times. The other advantages being it can carry more load which is very important since it operates under tremendous fluid pressure while compressing it and operating noise is less than as compared to spur gears which is specifically important as many times workers work near the pumps [2].

As it can be seen from the fig-1, the helical gears in the dry screw vacuum pumps are constantly in operation for long durations of time. Under such conditions, fatigue failure in gears and thrust bearing around them, is a major concern.

The objective of this paper is to find out the effect of change in root fillet radius (RFR) on mechanical properties of helical gears. The mechanical properties considered are maximum equivalent stress, maximum deformation, axial load and contact pressure. Similar research was done for spur gears in 2011 by Ashwini Joshi & Vijay Kumar Karma [3] and in 2019 contact stress analysis of spur gears was done by Jwan Khaleel Mohammed [4].

The analysis is done using Ansys Mechanical software and three different models of gear were taken with RFR was varying from 0.1 mm to 0.8 mm. The results were obtained in a tabulated format and graphs were plotted for better visualization.

2. Modeling

The helical gears were designed using solid works software according to standard gear designs as referred from Gear Design handbook [5]. Three gears were made as shown in Table-1, along with specifications. The specifications files were saved numerically and exported to Ansys for structural analysis.

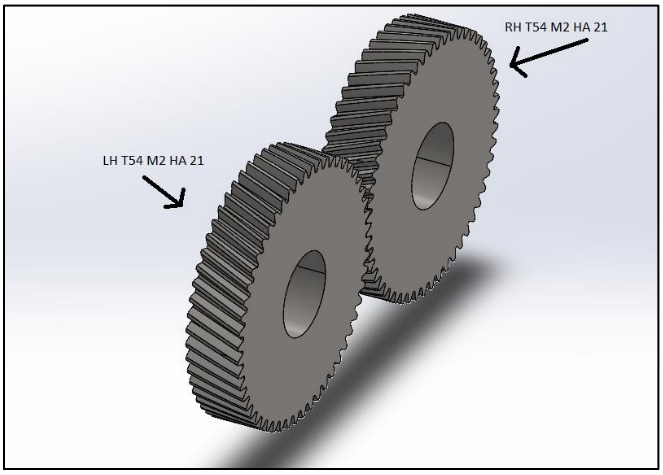

Fig-2: Helical gear assembly in solid works

	Gear 1	Gear 2	Gear 3
Number of Teeth	54	54	54
module	1.5mm	2mm	2.5mm
Helix Angle	21	21	21
Pressure Angle	20	20	20
Bore Dia.	35mm	35mm	35mm
Face Width	25mm	25mm	25mm

Table-1: Gear Specifications

The imported file was opened in Space claim and the RFR were parameterized as input parameters. Fig-3 shows the RFR of gears.

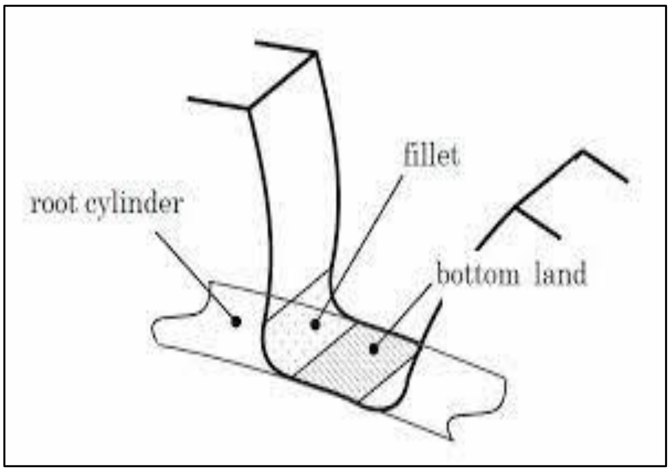

Fig-3: Root fillet radius in a gear

The material was assigned as 20MnCr5, common material used in manufacturing of gears. The properties listed are taken from Virgmet [6]

Properties	Value
Modulus of Elasticity(E)	210 GPa
Poisson's ratio	0.30
Density	7800 Kg/m^3
Yield Strength	>670 MPa
Tensile Strength	1000-1300 MPa

Table-2: Properties of 20MnCr5

Once the material is assigned, the mesh is generated using Ansys Mesh. The generated mesh looked like fig-4.

The mesh specification are listed in table-3. We used body sizing of 2 mm and made sure that the mesh metric values were of desired values as mentioned in Meshing Methods [7].

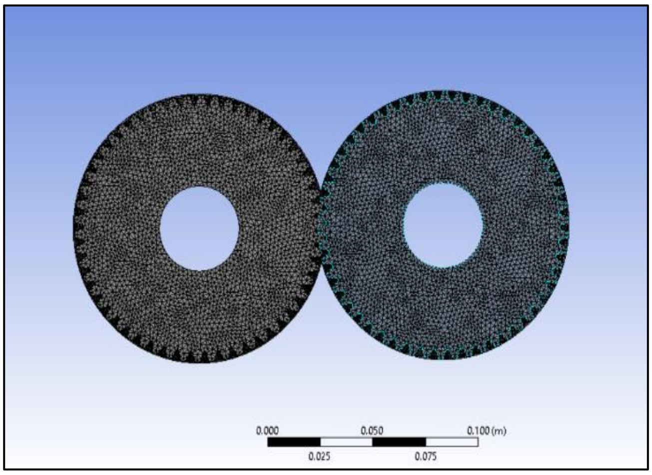

Fig-4: Helical gear meshing

	Gear 1	Gear 2	Gear 3
Type	Body Sizing 2mm	Body Sizing 2mm	Body Sizing 2mm
shape	tetragonal	tetragonal	tetragonal
Defeaturing size	0.1mm	0.1mm	0.1mm
Average Skewness	0.29	0.25	0.24
Orthogonality	0.69	0.74	0.74
Jacobian Ratio	1.02	1.016	1.007
Aspect Ratio	2.55	2.00	2.23

Table-3: Meshing Data

3. Analysis

One of the gear's bore was kept fixed support, the other had remote displacement which allowed only rotational movement along the rotating axis as in fig 5. The input torque was kept as 100 Nm.

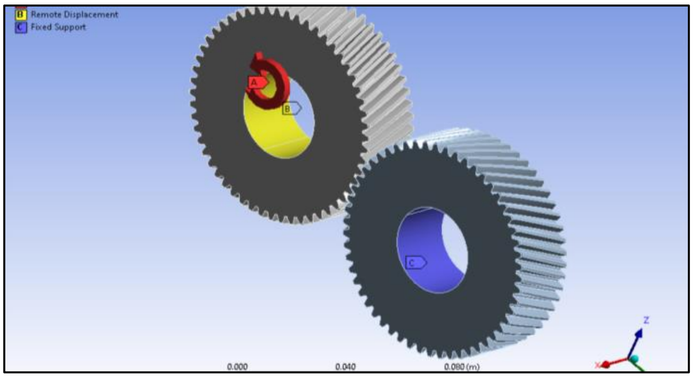

Fig-5: Boundary conditions of gear model.

Deformation, maximum equivalent stress, reaction forces at supports and contact pressure at contacts were kept as output parameters.

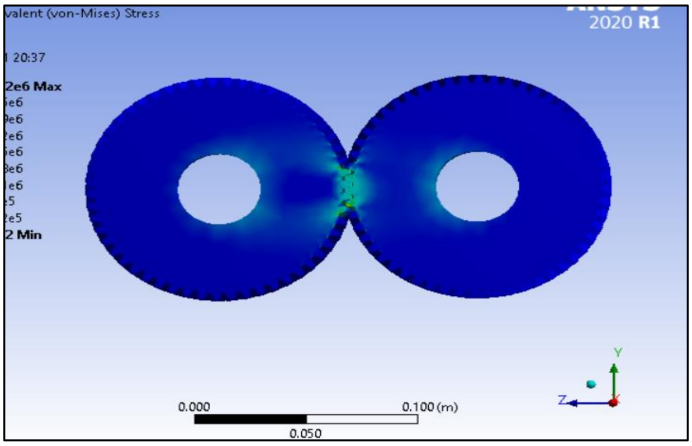

Fig-6: Stress in helical gears

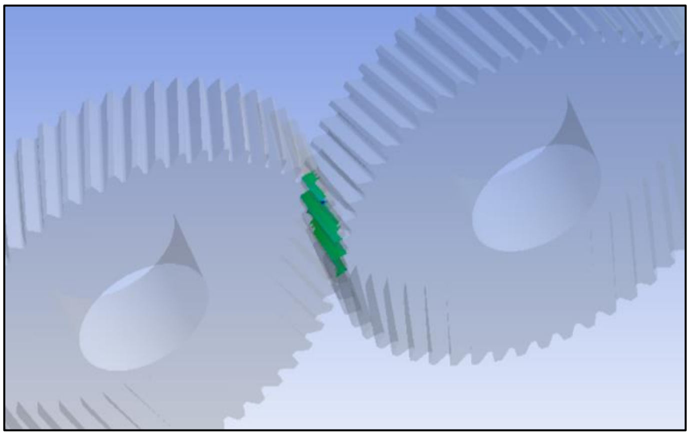

Fig-7: Contact Stress in helical gears

Fig-6 and Fig-7 show the maximum equivalent stress and contact stress in the helical gear assembly. Fig-5 shows that most the stress occurs around the contact region and around the supports whereas rest of the gear has almost no stress.

The analysis was solved with the initial given parameters, later on parameters were changed to get the results in a format.

4. RESULTS

The results were tabulated and data was analyzed by plotting graphs. The following things were concluded.

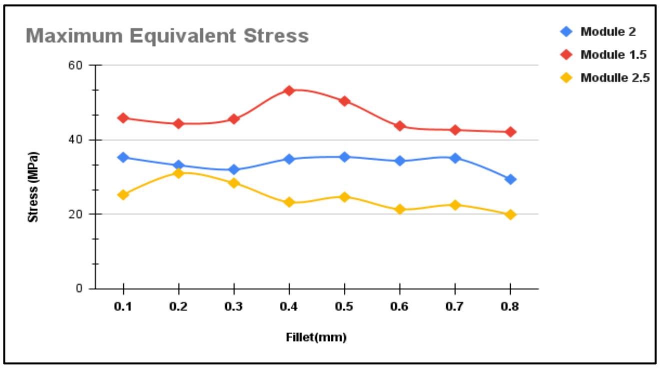

Fig-8: Maximum Equivalent Stress vs root fillet radius

The results for Maximum equivalent stress, as given in Fig-8, shows that the stress levels decrease with increase in module. There is also a rise in the value of stress at certain RFR values which are different for different modules.

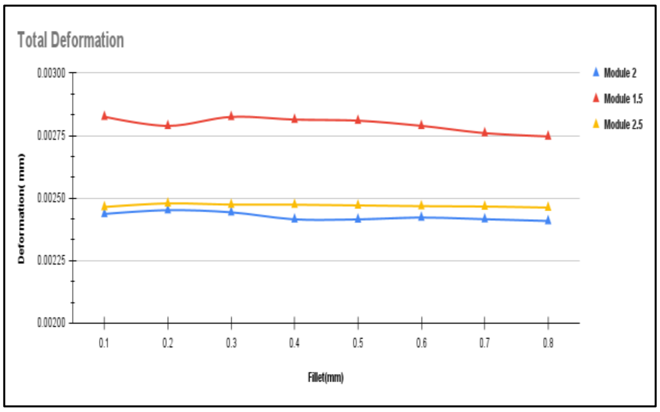

Fig-9: Total Deformation vs root fillet radius

The deformation also showed a decreasing trend with increase in module (shown in fig 9) but the effect of RFR on total deformation is insignificant.

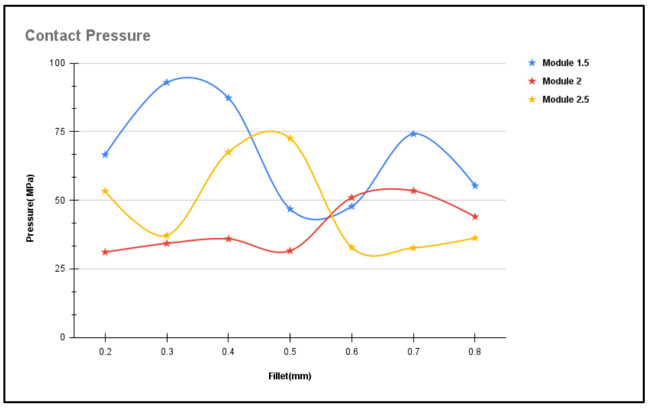

Fig-10: Contact Pressure vs root fillet radius

The contact pressure also showed a decreasing trend, but it shows a wavy nature (Fig 10) with maximum and minimum values at certain RFR. However no definite relation can be found for this wavy nature of contact pressure with RFR.

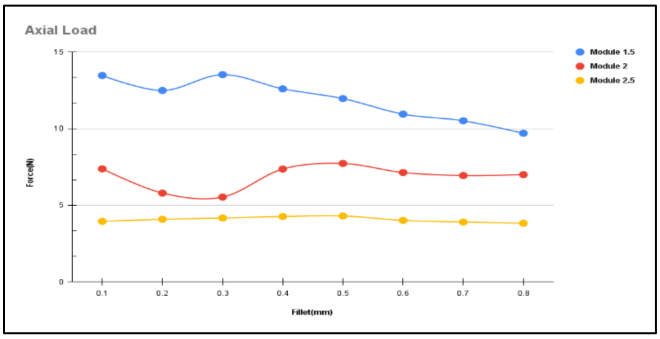

Fig-11: Axial load vs root fillet radius

The axial load also seemed to have a decreasing trend (Fig 11) with increase in module and the greatest drop in axial force was seen in gear 1(module 1.5mm) when RFR was increased. Minimum drop was seen in gear 3 (module 2.5mm).

One thing that needs to be understood is that Ansys is a CAE software and uses numerical methods for calculation of stress, deformation etc. However, its accuracy is dependent on how refined the grid or the mesh. However, making the mesh more refined also increases computational costs and time consuming. The quality of mesh is also dependent on the complexity of geometry with small features. In our research, we have kept the defeaturing size of 0.1 mm which means that any feature whose size is below 0.1 mm will not be taken into account.

5. CONCLUSIONS

A parametric study was done to study the effects of RFR in helical gears. The study was done on three different gear models of varying module. With the help of Ansys workbench, we were able to calculate the equivalent stress, deformation, contact pressure and axial load for different RFR. The important conclusions are as follows:

1. The maximum equivalent stress showed a decreasing trend with increase in module and RFR. There were sudden maxima at certain RFR values which were different for different modules.
2. The deformation also showed a decreasing trend with increase in module, but there was hardly any significant change in deformation with change in RFR.
3. The contact pressure also showed a decreasing trend with module and a wavy nature with increase in fillet radius.
4. The axial load also showed a decreasing trend with increase in module and RFR. However, the drop in axial load force with RFR decreased with increase in module. The greatest drop in force was at module 1.5mm and least at 2.5mm.
5. The axial load and maximum equivalent stress show some pattern with respect to maxima and minima. However, we need to do more analysis on other gears too of different module before making any conclusive statement.
6. By careful analysis of geometry, we can also say that RFR cannot be increased after a certain value because of space & width constraints. The degree to which it can be increased is dependent on the module and number of teeth.

Further research can be done by studying thees effects in low torque and high torque conditions, small increments in root fillet radius etc.

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