Parametric Computational Analysis of Lathe Gear System

Qazi Abdul Vajid Juned[1] Yogesh Kumar Deshmukh[2]
[1,2]Department of Mechanical Engineering
[1,2]Bharti Vishwavidyalaya, Durg, India

Abstract — In this work, the failure analysis of a spur gear on a lathe machine was explored using the finite element method. The lathe machine was used to perform the process. In this instance, the ANSYS geometrical module was utilised in order to construct a computational model of the spur gear that is found on a lathe machine. It has been determined that a parametric stress analysis of a spur gear is necessary in order to achieve the goal of optimising the performance characteristics of a spur gear when it is being subjected to both static and dynamic loads. A computer programme that was created in MATLAB was used to perform an analysis on the bending stress as well as the contact stress. This code was utilised in order to explore the impact of a variety of different elements, such as the transmission ratio, the width of the tooth face, and the number of teeth.

Keywords: Spur Gear, Lathe Machine, Bending Stress, Contact Stress

I. Introduction

In the realms of engineering and automobile manufacture, gear teeth serve a very significant purpose as features that are essential to the engineering process. When it comes to the design of spur gear teeth, the processes that are applied by designers and manufacturers the most frequently are those that include involvement and are constantly changing. As a result of their increased degree of compactness and reliability, gears are going to be able to take over as a main machine part that is built for power transmission in the technology of the future.

Because of the numerous scientific and technical developments that have taken place, computers have undergone major improvements and are becoming instruments that are becoming increasingly crucial. As a consequence of this, people have a propensity to adopt numerical methodologies in order to develop theoretical models in order to visualise the effects of the situation. Numerical methods are utilised because they provide a more accurate response, and this is due to the fact that they are less restricted in the assumptions that they make. In order to acquire accurate results, it is vital to choose the proper model and then approach the problem from a solution perspective. In addition, in order to confirm the findings in line with the trend, a significant amount of processing time is something that is necessary.

II. Literature review

Prior to the middle of the 20th century, the foundation for all gear design was an initial bending equation that was created by Lewis in the year 1893. Lewis's research was based on a cantilever beam, and he assumed that failure would occur at the point of the beam that was the weakest. This assumption has been proven to be correct. Following a thorough examination, Lewis came to the conclusion that the weakest part of the spur gear was the cross-section that was located close to the base of the gear.

Ramamurti and Rao conducted a stress research on spur gear teeth in 1988 using an approach that used fem and cyclic symmetry. The goal of this study was to observe the effects of stress on spur gear teeth. An asymmetrical loading pattern is imposed on the wheel as a whole as a result of the load that is delivered to the contact line at one of these substructures. Resolving this force system into a finite Fourier series allows for the calculation of the static stresses that are present. Danielewicz and Moore 1998 provide evidence that the fatigue life of gears may be extended with the application of compressive residual stresses through the use of restressing or presetting. Through the use of a single tooth bending fatigue fixture, these stresses were applied to spur gear teeth made of AISI 1040 steel. Additionally, each tooth was individually setup. [2] Faydor et al. 2005 presents latest computerized advancements in the design, generation, simulation of meshing, and stress analysis of gear drives. These advancements were made possible by the use of computer technology. Furthermore, they offer a numerical illustration of a hypothesis that has been shown to be correct. In order to improve the wear properties of vehicle gears, Lingamanaik and Chen 2012 suggest using metallurgical processes such as quenching and carburization to the gears. Martensite transition and the formation of a case-hardened surface layer are both necessary steps in order to achieve this goal. [4] Taking into consideration the fact that the martensite transformation process results in a volumetric expansion, which in turn subjected the surface to a state of 'compressive' residual stress, which in turn increased its resistance to fatigue, it is important to note that...

There is a physics model that Sheng and Kahraman (2014) provide that may be utilised for the purpose of calculating the micro-pitting behaviour that takes place on the contact surfaces of spur gears while they are operating in a mixed lubrication environment. One of the models that Li and Kahraman have created is a transient mixed elasto hydrodynamic lubrication model. It is vital to include in the transient effects that are connected with the time-varying contact radii, surface velocities, and normal tooth force when dealing with spur gear. This is because it is necessary to anticipate surface normal and tangential tractions.

Lu and Litvin [6] undertake an examination of the tooth surface contact and stresses within the context of double circular-arc helical gear drives based on their findings. Furthermore, the estimation of load sharing and contact ratio for both aligned and misaligned gear is carried out with the help of the finite element method.

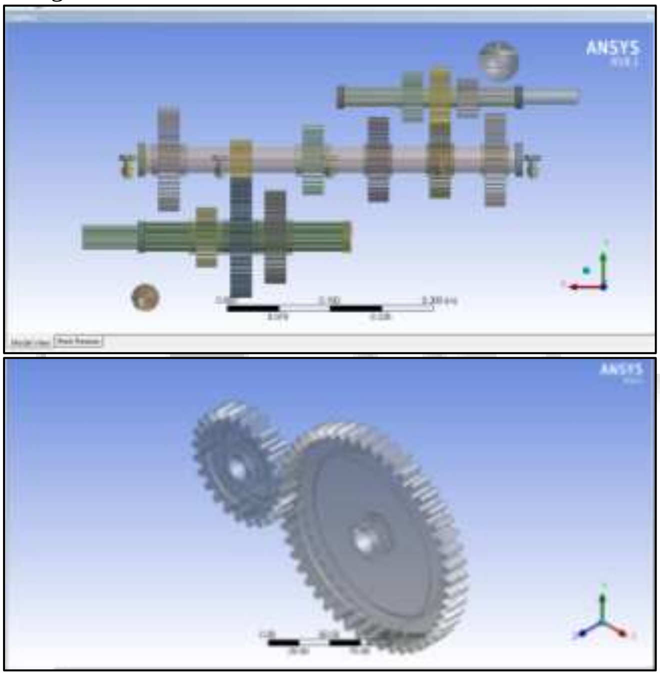
In order to improve the wear properties of vehicle gears, metallurgical processes such as carburization and quenching are used to the mechanism. According to Lingamanaik and Chen's assessment for the year 2012, this is achieved by promoting the transition to martensite and the formation of a surface layer that has been case-hardened. "[7]":

One of the models that Li and Kahraman have created is a transient mixed elasto hydrodynamic lubrication model. It is vital to include in the transient effects that are connected with the time-varying contact radii, surface velocities, and normal tooth force when dealing with spur gear. This is because it is necessary to anticipate surface normal and tangential tractions.

Utilising the Cubic Trigonometric Bézier function with two form parameters, Abbas et al. (2012) developed a spur gear as a result of their project. The low degree of form parameters and the availability of these factors result in this design offering additional freedom for interactive design. To further assess whether or not the tooth design is appropriate, the design was subjected to finite element analysis (FEA), which was performed on the design.

III. MATHEMATICAL MODEL

The geometry of the problem herein investigated is depicted in Fig. 1.



Spur Gear
Fig. 1: Model Configuration

A. *The FEM Formulation*

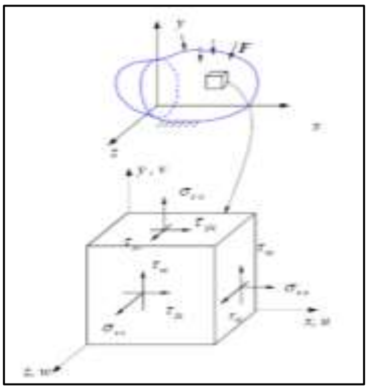


Fig. 2: Infinitesimal element showing stress state [9].

B. *Displacement*

$$U = \{u(x,y,z), v(x,y,z), w(x,y,z)\}$$

Cauchy's Stress tensor =

$$\sigma = \begin{bmatrix} \sigma_{xx}\tau_{xy}\tau_{xz} \\ \tau_{yx}\sigma_{yy}\tau_{yz} \\ \tau_{zx}\tau_{zy}\sigma_{zz} \end{bmatrix}$$

The strain-stress relations (Hooke's law)for isotropic materials are given by [9]:

$$\begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{xz} \end{Bmatrix} = \frac{1}{E}\begin{bmatrix} 1 & -\nu & -\nu & 0 & 0 & 0 \\ -\nu & 1 & -\nu & 0 & 0 & 0 \\ -\nu & -\nu & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(1+\nu) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(1+\nu) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(1+\nu) \end{bmatrix}\begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix}$$

Strain-Displacement relations are:

$$\varepsilon_{xx} = \frac{\partial u}{\partial x}, \varepsilon_{yy} = \frac{\partial v}{\partial y}, \varepsilon_{zz} = \frac{\partial w}{\partial z}, \gamma_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y},$$

IV. RESULT AND DISCUSSION

The parametric study of effect of face width, Pressure Angle, varying load, no. of teeth on Spur gear is carried out.

The MATLAB results are validated with literature and by Analytical calculation for a few cases are also illustrated.

No of teeth(N)	MATLAB Stresses(MPA)	3D Stresses (ANSYS)(MPA)
22	130.1847	130.67
23	126.8841	127.44
25	122.2941	122.6
28	120.4364	120.55
30	119.0751	119.67
34	117.4243	117.63

Table 1: Validation of Von-Mises (Bending) Stresses for Spur gear Models

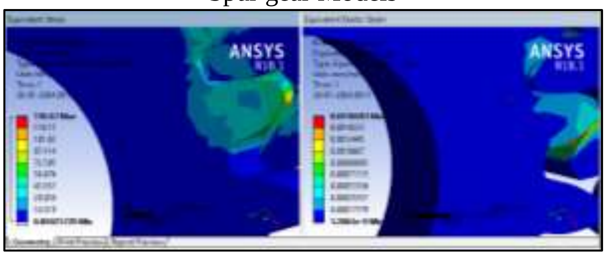


Fig. 3: 3-D Von-Mises Stress for Gear with 19 Teeth

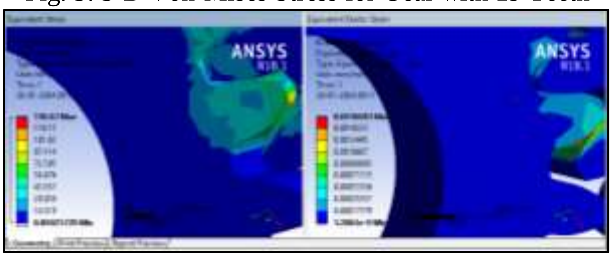


Fig. 4: 3-D Von-Mises Stress for Gear with 24 Teeth

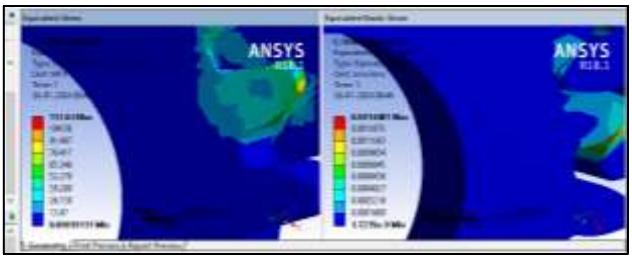


Fig. 5: 3-D Von-Mises Stress for Gear with 34 Teeth

Effect of number of tooth and tooth face load in bending stress

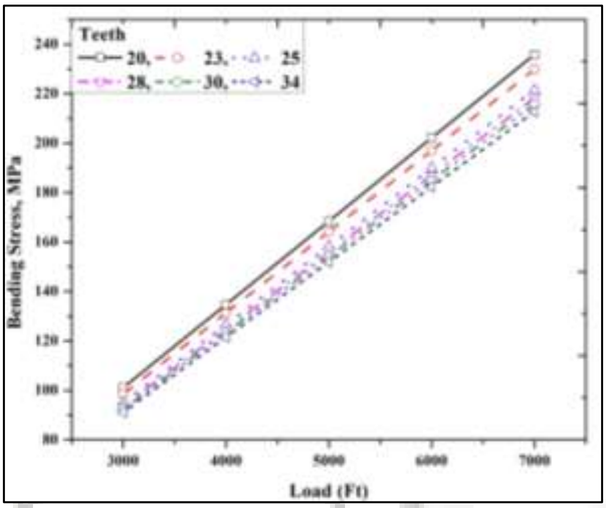


Fig. 6: Variation of Bending Stress with respect to Tangential load and no. of Gear Teeth

Figure 6 provides a visual depiction of the change in bending stress that occurs in relation to the tangential load and the number of gear teeth. It is feasible to derive the conclusion that the bending stress increases in a linear way when the number of teeth grows in response to the tangential load. This is because the tangential load is a linear relationship. If there is a bigger weight, then there will be a greater bend in the structure. It is possible to reduce the amount of bending stress by increasing the number of teeth that are present in the structure.

As a consequence of this, the number of teeth is an important factor that is considered throughout the design process of the gear in order to determine the performance characteristics of the gear. The dynamic factor kv, the overload factor ko, and the j geometry factor are also some of the characteristics that should be considered.

A. Influence of Pressure Angle on Contact Stress with Respect to Transmission Ratio

A representation of the relationship between the pressure angle and contact stress is shown in Figure 7, which is situated within the context of the gearbox ratio. In this illustration, the gearbox ratio serves as a representation of this connection. The contact stress has been demonstrated to decrease in a linear fashion as the pressure angle increases in a manner that is proportional to the gearbox ratio. This has been demonstrated through a number of studies. Someone made this discovery. As a result, in order to get rid of the contact stress, it is possible to enhance the gearbox ratio and pressure angle to the maximum limit that is in accordance with the criteria. It is not impossible to do so.

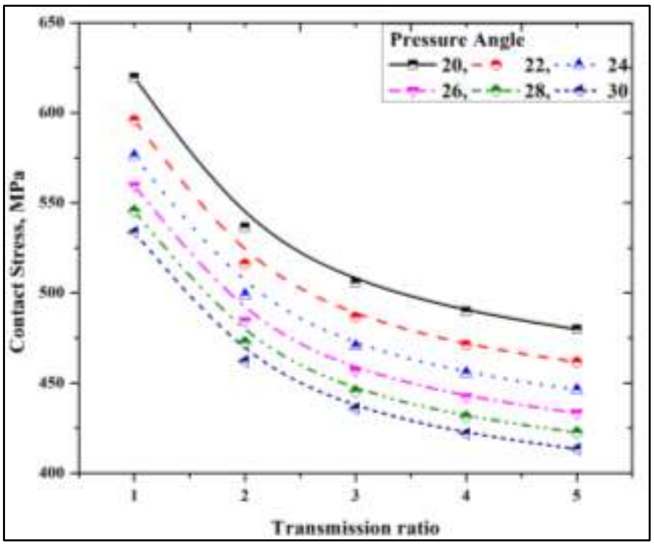


Fig. 7: Influence of pressure angle on contact Stress with respect to transmission ratio

V. CONCLUSION

The following discoveries have been made as a consequence of the failure investigation that was conducted on the spur gear that was flowing:

Within the range of ±.0122 to ±.02014, the range of disparities that might be found between the findings produced from MATLAB and ANSYS is considered statistically significant.

It has been shown that the stresses that are imposed on the teeth of the spur gear undergo a change that is proportional to the number of teeth that are present in the spur gear.

Increasing the pressure angle results in a decrease in the contact ratio as well as the fraction of gears that overlap.

It is strongly recommended that the tooth pressure angle be increased in order to optimise the load bearing capabilities of the tooth. This is because of the reasons stated above.

REFERENCES

[1] V. Ramamurti, M.Ananda Rao, “Dynamic analysis of spur gear teeth” , Computers & Structures, Volume 29, Issue 5, 1988, Pages 831-843

[2] S.R Daniewicz, D.H Moore ,“Increasing the bending fatigue resistance of spur gear teeth using a presetting process, International Journal of Fatigue, Volume 20, Issue 7, August 1998, Pages 537-542

[3] Faydor L. Litvin, Daniele Vecchiato, Eugene Gurovich, Alfonso Fuentes, Ignacio Gonzalez-Perez, Kenichi Hayasaka, Kenji Yukishima, “Computerized Developments in Design, Generation, Simulation of Meshing, and Stress Analysis of Gear Drives”, Meccanica, June 2005, Volume 40, Issue 3, pp 291-323

[4] Siva N. Lingamanaik, Bernard K. Chen, “The effects of carburising and quenching process on the formation of residual stresses in automotive gears”, Computational Materials Science, Volume 62, September 2012, Pages 99-104

[5] Sheng Li, Ahmet Kahraman, “A micro-pitting model for spur gear contacts”, International Journal of Fatigue, Volume 59, February 2014, Pages 224-233
[6] J. Lu, F.L. Litvin, J.S. Chen, “Load share and finite element stress analysis for double circular-arc helical gears”, Mathematical and Computer Modelling, Volume 21, Issue 10, May 1995, Pages 13-30
[7] Siva N. Lingamanaik, Bernard K. Chen, “The effects of carburising and quenching process on the formation of residual stresses in automotive gears”, Computational Materials Science, Volume 62, September 2012, Pages 99-104
[8] Sheng Li, Ahmet Kahraman, “A micro-pitting model for spur gear contacts”, International Journal of Fatigue, Volume 59, February 2014, Pages 224-233
[9] Reddy, J.N., 2005,” An introduction to the finite element method”, Tata McGraw Hill education private limited, New Delhi.
[10] Muhammad Abbas, S.H. Yahaya, Ahmad Abd Majid, Jamaludin Md. Ali ,“Spur Gear Tooth Design with S-Shaped Transition Curve using T-Bézier Function”, Procedia Engineering, Volume 50, 2012, Pages 211-221