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PERFORMANCE ANALYSIS OF LATHE GEAR TEETH FAILURES BY FINITE ELEMENTS METHOD

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ABSTRACT

Gear is one of the very useful elements in lathe machine for transmitting power from the input motor shaft to the other engaging output shaft, Due to the smallness and reliability of gears. It will defeat the power losses so it has important machine element designed for transmitting the power in prospect technology. In lathe machine power transmitted by means of gear in lower as well as higher rate as per our requirement. Therefore it plays a significant role in any operation on lathe. In this work investigate the performance analysis of lathe gear teeth failures by finite elements method, **so a** computational tool ANSYS is used to solve the governing equation. The goal will be achieved by design studies of 3D finite element models of spur gear to inspect the gear tooth root bending stresses and contact stresses under application of boundary conditions. The geometric model of spur gear of lathe machine will be ready in ANSYS where boundary conditions are apply on it and results are generated, that are compared with the available literatures data.

During analysis various parameters will be undertaken that are as follow:-

- Transmission ratio effect on the contact stress for different face width
- Tangential load effect on the contact stress for different Face width
- Pressure angle effect on the contact stress for different Face width
- Tooth face effect on the bending stress
- Number of teeth effect on Von-Mises Stress
- Optimum operating condition of gear in lathe machine will be proposed in order to prevent from failure

Keywords : Spur Gear, FEM, Contact Stress, Bending Stress and ANSYS.

I INTRODUCTION OF GEAR

Gears are one of the very useful methods for transmitting power from the input motor shaft to the other engaging shaft and the engagement of gears with or without changing the direction and speed of the shaft. Due to very smallness and reliability, Gears will become a noteworthy machine element designed for transmitting power in prospect technology. In this work study investigate the performance analysis of lathe gear tooth failures by (FEA) finite elements method. The essential requirement of proficient power transmission in different machines likes generators, automobiles and elevators etc. has created necessity for a more accurate analysis of the individuality of gear arrangements.

The classic gear analysis had done by the help of analytical methods with lots of assumptions and typical solutions. In general gear analysis are computations related to the gear tooth stresses and failures of contacting teeth. In this work we study of bending stress analysis are performed by the help of ANSYS. The main mottos are designing spur gears to reduce bending stresses.

II. MATHEMATICAL MODELING AND EQUATIONS:-

In FEM the complex problem domain is disgraced into simple finite elements. Whose properties are pre-defined and the given governing differential equation is generally satisfied of the each element using certain mathematical rules (generally Gauss quadratic). The element equations are compiled together to get a global set of algebraic equations which are solved after announcing the boundary conditions (specified values of parameters are their derivatives at definite nodes). The nodal parameters so obtained are interpreted, appropriately to post-process the required solution for the problems.

2.1 Types of Stresses into Gears Tooth

Two types of stresses induced in the gear tooth, root bending stresses and tooth contact stresses. These stresses are accountable for the failure of gear teeth, due to root bending stress fatigue fracture occurs in the tooth and due to contact stresses pitting failure occurs at the contacting tooth surface. There for both these stresses are to be considered when designing a lath gear.

2.2 Bending Stress of Gear Tooth

Sir Lewis considered tooth of the gear as a cantilever beam with static normal force F applied at the tip of the gear tooth.

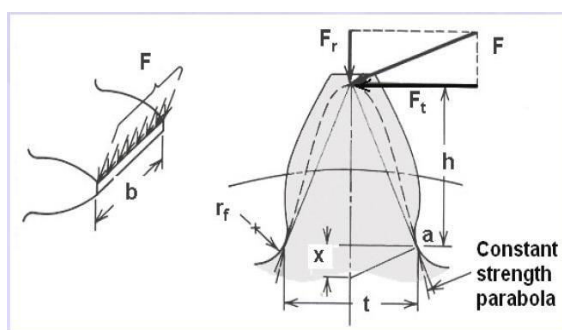


Fig.1 Tooth of the Gear as a cantilever beam

The bending stress given by Lewis equation is

$$F_t = \sigma \pi mbpy$$

(2.1)

Here,
F_t= Tangential Transmit load,
b = Face width of tooth
p = Circular pitch of gear, m = Module,
y= Lewis form factor.

The equation below is the AGMA bending stress equation for S.I specification of gears.

$$\sigma_b = \frac{F_t K_v K_m K_0}{mbY} \quad (2.2)$$

Here,

F_t= Tangential Transmit Load,

K_v= Load distribution factor,

K_m= Dynamic Factor,

K_o= Overload factor, b = Face Width of tooth

2.3 Tooth Contact Stress

The most of engineering elements such as rolling bearings, gears, cams, etc., machine elements those working depends on rolling and sliding motion in contact along matching surfaces while the under loads. Here the matching surfaces are non-conformal, hence the resulting contact areas are very small and the pressures on the surface are very high. This is the view point of gear design, it is crucial to know the values of stresses are acting in such contacts surfaces. That stresses can be determined from the systematic formulae, based on the theory of elasticity, established by Hertz.

Von-mises stress is

$$\sigma_{von} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \quad (2.3)$$

Contact Stress AGMA Equations

Two fundamental stress equations are used in the American Gear Manufacturer Association (AGMA) methodology, According to Shigley the fundamental equation for pitting resistance (contact stress) is

$$\sigma_p = y_m y_p \sqrt{\frac{F_t(u+1)}{bdu}} \quad (2.4)$$

- **Model the Geometry of Spur Gear**
  - We follow the bottom up modeling and create the geometry in ANSYS geometric platform or it is import from other Design-modeling software likes Pro-E ,Solid works, Catia and Solid Edge etc. in the "iges" format which is compatible into the ANSYS.

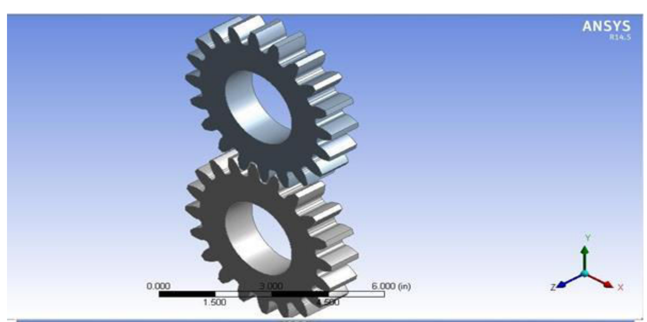


Fig. 2 Geometric Model of Spur Gear

- **Define element type. i.e. solid 186**
- **Mesh. i.e. Sweep mesh, Mapped**

The gear was discredited into 7208 elements with 39127 no. of nodes.

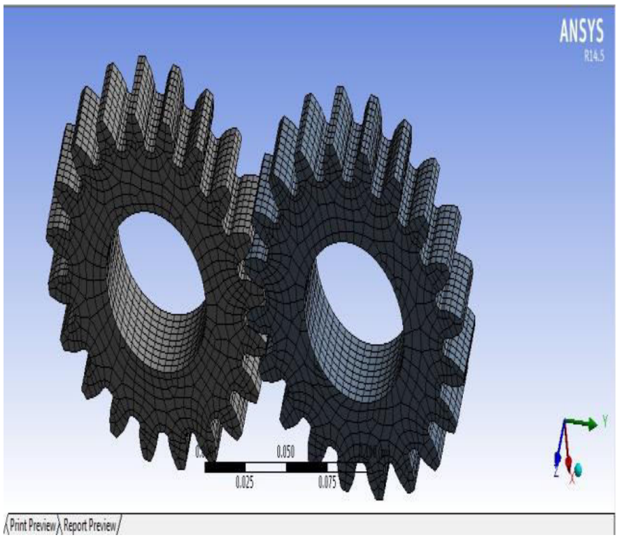


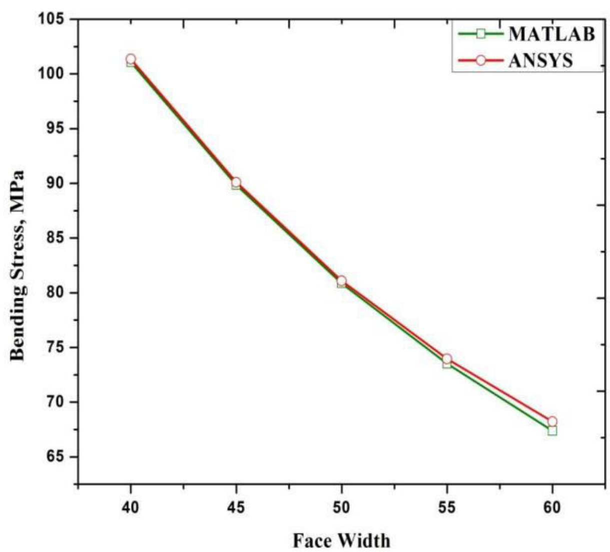
Fig. 3 Meshing of Spur Gear Model

III RESULTS AND DISCUSSION

We obtained results from ANSYS investigation has been compared and validated with the results available in literature and few case studies has also been clarified regarding about the calculation of stress in the tooth.

Table 1. Von-Mises (Bending) Stresses Validation of Spur Gear Models

No. of Teeth(N)	ANSYS Stresses (MPA)	MATLAB Stresses (MPA)
22	131.53	130.1847
23	126.28	126.8841
25	123.89	122.2941
28	122.94	120.4364
30	120.45	119.0751
34	117.45	117.4243



it can also be concluded that the Von-Mises (Bending) Stresses decreases as the number of teeth of spur gear increases.

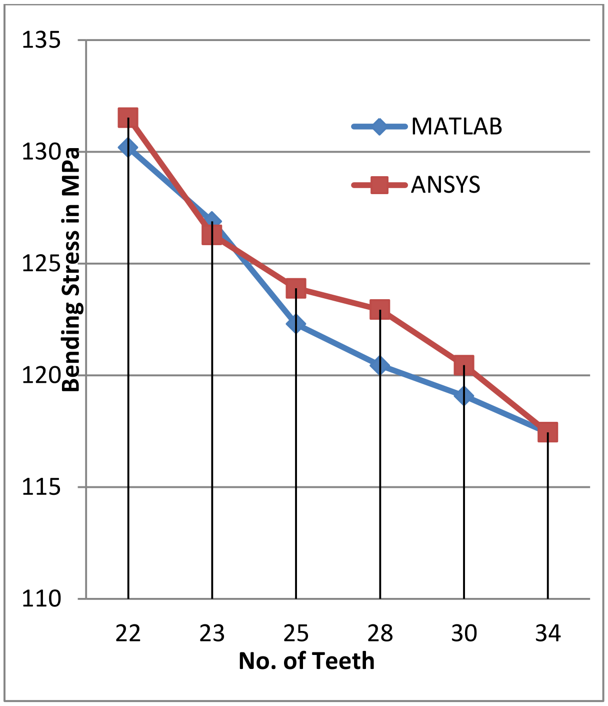


Fig 4. Number of Teeth Effects on Stresses of Spur Gear

Table 2. Face Width Effects on Bending Stress

Face Width (mm)	ANSYS (MPa)	MATLAB (MPa)
40	101.352	101.0744
45	90.0922	89.84352
50	81.0791	80.85918
55	73.9543	73.50834
60	68.2234	67.38245

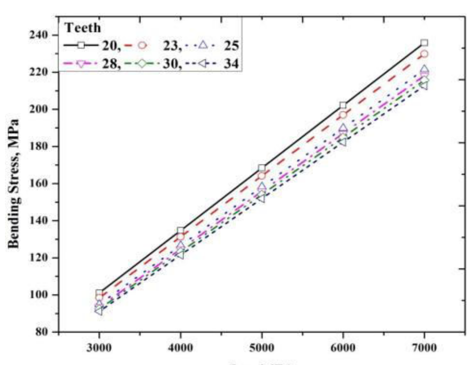


Fig. 5. Gear face width effects on Bending Stress

That has been observed that as the gear face width rises, the bending stress significantly decreases. The Bending stress results from ANSYS shows good agreement with the MATLAB result the variation of ±0.0027% is there. On comparing the result ±0.0027% variation has been seen between MATLAB bending stress and the result calculated from ANSYS.

Table 3. Tangential load and no. of Gear Teeth Effects on the Bending Stress

Tangential Transmit load	Gear Teeth					
	20	**23**	**25**	**28**	**30**	**34**
3000	101.0741	98.51137	94.9477	93.50542	92.44871	91.16694
4000	134.7652	131.3486	126.5972	124.6737	123.2647	121.5568
5000	168.4565	164.1856	158.2462	155.8424	154.0813	151.9457
6000	202.1482	197.0227	189.8955	187.0106	184.8973	182.3349
7000	235.8392	229.8598	221.5447	218.1793	215.7131	212.7238

Fig. 6. Tangential load and no. of gear teeth effects on bending stress

It can be conclude that the bending stress increases linearly as the number teeth and tangential load increases.

Table 4. Tangential load effects on the contact Stress as compare to different face width

Tangential load	Gear Face Width				
	40	45	50	55	60
3000	615.0774	579.9005	550.141	524.5398	502.2088
4000	710.2304	669.6114	635.2492	605.6866	579.9007
5000	794.0615	748.6484	710.2302	677.179	648.3487
6000	869.8508	820.1032	778.0181	741.8115	710.2304
7000	939.5463	885.8127	840.3557	801.2478	767.1363

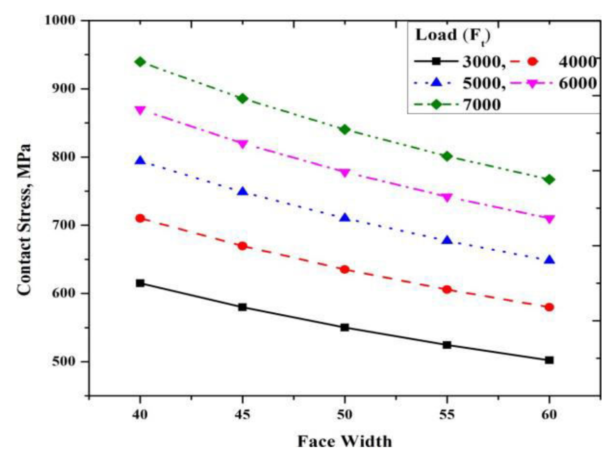
Fig. 7. Tangential load effects on contact stress with respect to different face width

It has been observed that the contract stress increases linearly as the tangential load increases. But concurrently at a same occasion increasing gear face width, the contact stress decreases linearly.

IV Conclusions-

Stress analysis of a lathe spur gear done by using ANSYS tool, so the following conclusions has been drained which are as follows-

- This is concluding that the contact stress within the pair of lath spur gear improved on varying the number of teeth of spur gear.
- The comparing obtained from ANSYS results with MATLAB result (maximum bending stresses) and Hertz theory (contact stresses) the concluded that the ANSYS have maximum stresses.
- On comparing the results are obtaining from MATLAB and ANSYS the results are lies in the range of ±.0122 to ±.02014 variations.
- When the gear tooth contact stress decreases linearly then the pressure angle increases



significantly.

- When the gear tooth face width increasing the contact stress decreases linearly.

- The contact stress decreases concurrently as transmission ratio consistent to pressure angle increases.
- For the gear safety, it is highly recommended that the gear tooth face width help to reducing contact stresses.
- To increase the load bearing capacity, it is recommended that the pressure angle should be increased.
- On the basis of stress concentration only the tooth height should be varied. While, the shorter gears have more stress concentrated area therefore, practically large gears are preferred.
- Gear tooth face width and transmission ratio have significant parameters in the gear design. On the basis of results it is conclude that as gear tooth face width increases the bending stress decreases and the value of bending stress maximum, when low face width used along with higher transmission ratio.

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