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ANALYSIS OF CONTACT STRESSES OF GEARS ON METAL CUTTING MACHINES

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Abstract
The contact stress in the mating wheels is a key parameter in gear design. This article presents an analysis of the contact stresses of a pair of spur gears as the second gear in the gearbox of the NT – 250M lathe in order to determine the maximum stress in the gear teeth. The contact stresses obtained from the theoretical values of the Hertz equation are compared with the finite element analysis method. Spur gears are modeled and assembled in SolidWorks V20 software and executed using ANSYS V21 software.

Keywords: Contact stress, ANSYS, spur gear, Hertz equation, power, torque, speed.

INTRODUCTION

Gears are one of the most important elements of power transmission as they play a significant role in the mechanical engineering industry. Gears are used to transmit power and rotational motion between parallel shafts. This is one of the simplest types of gears. Surface failure of a gear tooth is pitting when the contact stress exceeds the surface fatigue strength of the material. In this work, the contact stresses in the contact zone between spur gear pairs are studied using the finite element method under static conditions [1, 5, 8].

The contact stress in the mesh of a pair of gear teeth determines the gear's ability to transmit power without harm. Contact stress in gears has played an important role in recent years, but extensive research is still needed to understand some of the parameters affecting this stress. Among these parameters, the most important factors affecting surface contact stress are; material, number of teeth, module and wheel width. In the present study, the contact stress in a spur gear is calculated by varying one of these parameters and keeping it constant to obtain the effect of each parameter on the contact stress separately based on the HERZ equations and the finite element method (FEM).

Pitting failure of a gear tooth occurs due to misalignment, improper selection of oil viscosity, and contact stress exceeding the yield strength of the material. The material in the fracture zone is removed and a hole is created. Consequently, the higher impact load resulting from pitting can lead to the destruction of an already weakened tooth. The performance and life of gear teeth is directly related to the teeth's ability to withstand contact stresses. To increase service life, gear analysis is critical to preventing pinpoint failure [4, 6].

Contact stress can cause pitting in the tooth; Therefore, the contact stress must be within acceptable limits. To explain the behavior of contact stress, stress analysis must be performed. Among the main influencing factors are; The geometric profile of the tooth (material, number of teeth, modules and wheel width) can be discussed.

Vivek Karaveer, Ashish Mogrekar and T. Preman Reynold Joseph explained the stress analysis of a spur gear to find the maximum contact stress in the teeth. They compared the results of the FEA analysis with the Hertzian contact equation for the materials gray cast iron and steel. They created the model in ANSYS Design Modeler and the analysis was performed using ANSYS software. They concluded that the stress values of steel and gray cast iron gears are comparable [8]. S Mahendran, K. M. Eazhil, and Senthil Kumar studied weight reduction and stress distribution, impact analysis, torsional loading of cast steel and composite materials for the Tata Super Ace model. Gear modeling is done using SOLIDWORKS software and analysis is done using ANSYS software. They compared and analyzed composite gears with cast steel. They concluded that the stress, deformation and weight values of spur gears made of composite material are less than those made of cast steel [6].

Table 1 Material properties

Property	Steel 40X GOST 4543 – 2016	Stainless steel 05X16H4Д2Б	Aluminum
Density (g/cm^3)	7,82	7,78	2,7
Young’s modulus (GPa)	214	196	70
Poisson’s ratio	0,3	0,3	0,3

The purpose of the work is to analyze the contact stresses of a pair of spur gears of the second gear of the gearbox of the NT – 250M lathe. The contact stresses obtained from theoretical calculations are compared with the finite element method. Steel 40X GOST 4543 – 2016, stainless steel 05X16H4Д2Б, and aluminum.

Project description: Modeling is performed using Solidworks V21 software (Fig. 1). The maximum contact stress of a spur gear is determined when transmitting a torque of 95.5 Nm using Steel 40X GOST 4543 – 2016, stainless steel 05X16H4Д2Б, and aluminum materials using finite element analysis.

Table 2 Spur gear dimensions

Options	Gear	Wheel
Number of teeth (pieces)	Z_1=30	Z_2=60
Module normal (mm)	m_n=3,5	m_n=3,5
Normal source contour	GOST 13755 – 2015	GOST 13755 – 2015
Pitch diameter (mm)	105	210
Wheel width (mm)	b_1=29	b_2=29

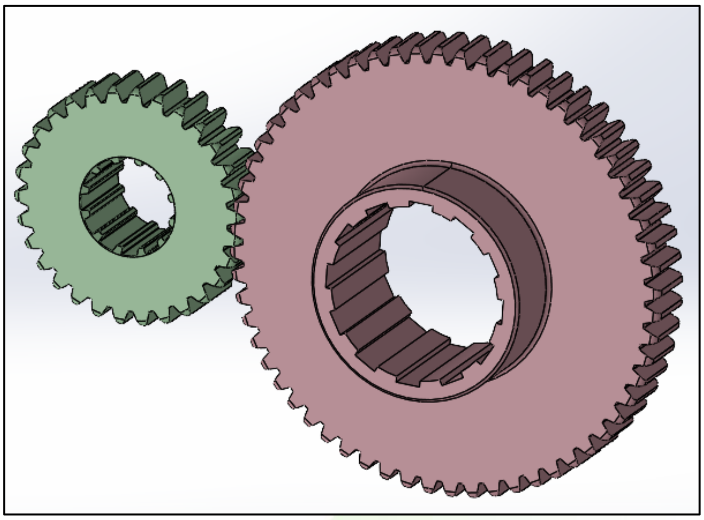


Fig. 1. Assembling a set of spur wheels

Technical characteristics and design calculations

Table 3 Specifications

Model	Lathe NT – 250M
Engine power	10 kW
Maximum torque	95.5 N/m=95500 N/mm
Maximum speed per rotation	1000 rpm

Theoretical calculation of contact stress (Hertz equation)

Contact voltage for Steel 40X GOST 4543-2016

$$\sigma_c = \sqrt{\frac{F(1+\frac{R_1}{R_2})}{R_1 \times B \times \pi(\frac{1-\mu_1^2}{E_1}+\frac{1-\mu_2^2}{E_2})\sin\alpha}} \quad (1)$$

$\boldsymbol{\sigma_c}$ *– Maximum contact stress value (N/mm²)*
F *– Force of compression of two cylinders together (N)*
B *– Wheel width*
$\boldsymbol{\mu_1}$ *– Poisson's ratio of 1 – cylinder*
$\boldsymbol{\mu_2}$ *– Poisson's ratio of 2 – cylinder*
$\boldsymbol{E_1}$ *– Modulus of elasticity of the 1 – cylinder (N/mm²)*
$\boldsymbol{E_2}$ *– Modulus of elasticity of 2 – cylinder (N/mm²)*
$\boldsymbol{\alpha}$ *– pressure angle* 20^0

$$m = F \times R \quad (2)$$

$$F = \frac{m}{R}$$

m – Torque (N/m)
F – Force of compression of two cylinders together (N)
R – Gear pitch radius (m)

$$F=\frac{95,5}{0,0525}=1819\, H\!\big/\!_{m}$$

$$\sigma_c=\sqrt{\frac{1819(1+\frac{105}{210})}{105\times19\times3,14(\frac{1-0,3^2}{214^3}+\frac{1-0,3^2}{214^3})\sin20^\circ}}=2995MPa$$

Analysis of contact stress calculation using finite element method. Creating a mesh.

In FEA analysis, the computational domain is discretized into a number of elements, and element nodes are known as grid points. The process of discretizing an area is called meshing. The fine mesh is made with a size of 1 mm (Fig. 2).

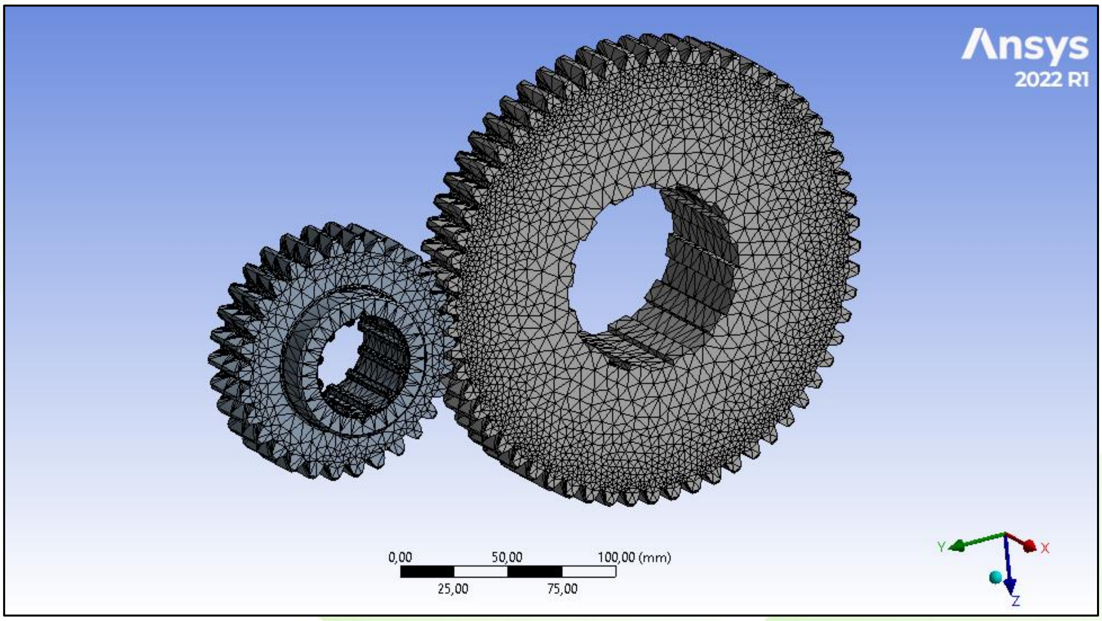


Fig.2. Typical view of a spur gear with meshing

Border conditions

A frictionless support is applied to the inner rim of the gear, and to the inner rim of the wheel (Fig. 3).

A torque of 95.5 Nm is applied to the gear in a clockwise direction as torque (Fig. 4).

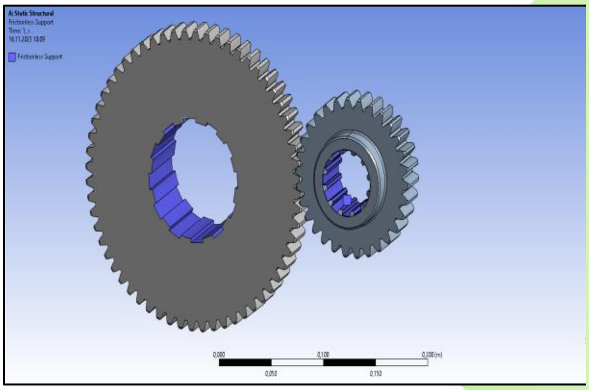


Fig.3. Boundary conditions on a spur drive

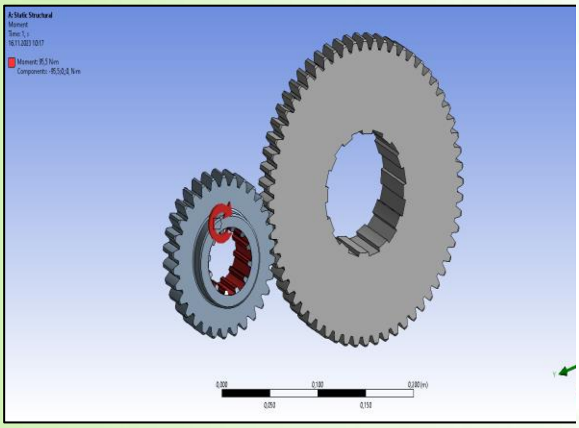


Fig.4. Application of torque to a gear

FEA results Steel 40X GOST 4543-2016 (Fig. 5)

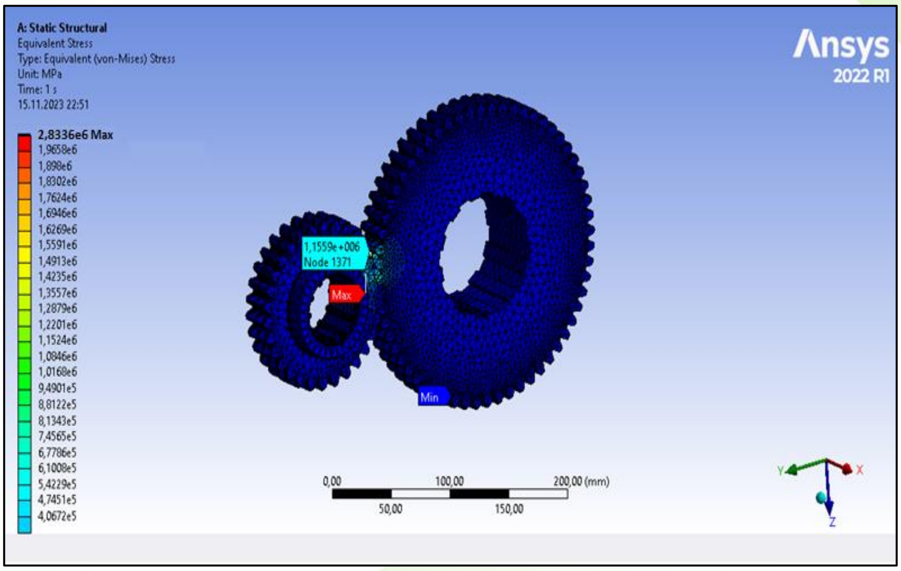
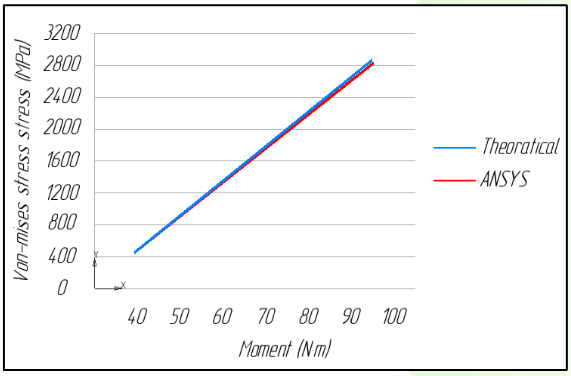
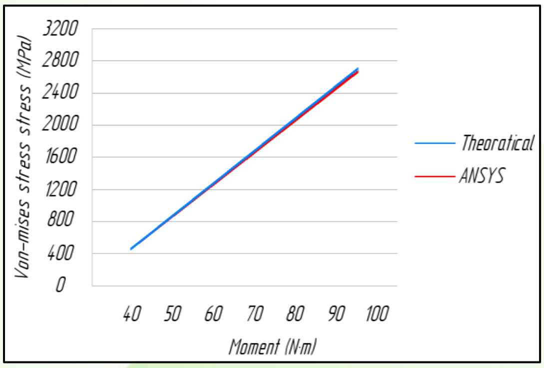


Fig. 5. Equivalent stress (von – Mises)

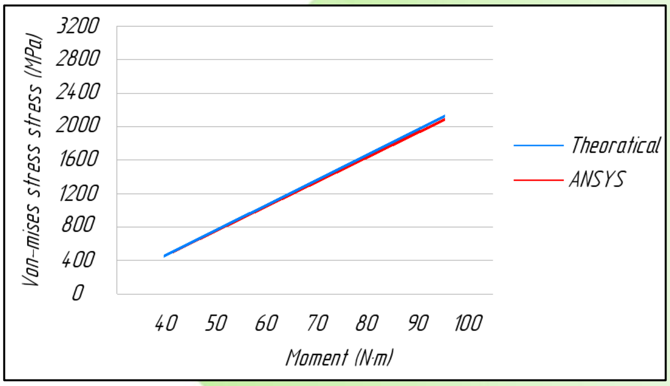


Graph 1. "Moment depending on von Mises stress" for steel 40X GOST 4543 – 2016



Graph 2. "Moment depending on von Mises stress" for Steel 05X16H4Д2Б

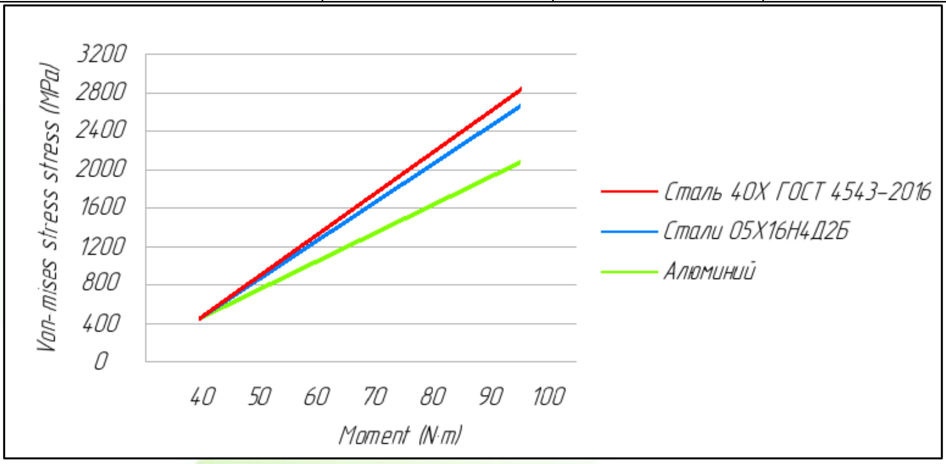
We repeat the calculation in a similar way for Steel 05X16H4Д2Б and Aluminum.



Graph 3. Torque versus von Mises stress for Al

Table 4 Comparison of contact stress obtained from the Hertz equation with FEA results

Material	Contact voltage		
	ANSYS	HERTZ	Error
Steel 40X	2833	2995	5%
Steel 05Х16Н4Д2Б	2611	2783	6%
Aluminum	2155	2261	5%



Graph 4. Moment depending on the von Mises stress for Steel 40X GOST 4543 – 2016, stainless steel 05Х16Н4Д2Б, and aluminum

CONCLUSION

The difference between the theoretical contact stress results of a spur drive and the FEM results is very small. Therefore, both results are comparable. The theoretical von Mises stress for Steel 40X GOST 4543 – 2016 and the FEA results for Steel 40X GOST 4543 – 2016 are comparable. Similarly, the theoretical contact stress of Steel 05Х16Н4Д2Б, Aluminum and FEA results are comparable. We came to the conclusion that the stress caused in Steel 40X GOST 4543 – 2016 material is higher than that of Steel 05Х16Н4Д2Б and Aluminum, and the stress caused in the material of Steel 05Х16Н4Д2Б is higher than in Aluminum, so we believe that stainless Steel and Aluminum the material is better suited than alloy steel for minimizing stress in the gear train.

REFERENCES

1. Abdullah Akpolat. Analysis of Contact Stresses in Spur Gears by Finite Element Method // European Journal of Science and Technology. December, 2019. No. 17, pp. 539-545.
2. Farhan, M. Karuppanan, S. and Patil, S. S. Frictional contact stress analysis of spur gear by using Finite Element Method. in Applied Mechanics and Materials // Trans Tech Publications. 2015. No. 772, pp.159-163.
3. Huei-Huang Lee. Finite Element Simulations with ANSYS Workbench 14 // SDC Publications. 2012. Pp. 142-147.

4. Kristina Markovic, Marina Franulovic. Contact Stresses in Gear Teeth due to Tip Relief Profile Modification // UDC 621.833.15:62-233.5. 2011Pp. 19-26.
5. Sachin Almelkar, Prof I.G.Bhavi.. Comparison of analytical and FEA of contact analysis of spur gear drive // International Research Journal of Engineering and Technology (IRJET). 2016. Volume. 03 Issue. 09. pp. 620-624.
6. S. Mahendran, K. M. Eazhil, and Senthil Kumar. Design and analysis of composite spur gear // IJRSI November 2014.Vol.1, Issue.6.
7. Vera Nikolic-Stanojevic, Ivana (Atanasovska) Cvejic. The Analysis of Contact Stress on Meshed Teeth's Flanks Along the Path of Contact for a Tooth Pair // Mechanics, Automatic Control and Robotics, 2003. Volume 3, Pages 1055-1066.
8. Vivek Karaveer, Ashish Mogrekar and T. Preman Reynold Joseph. Modeling and FEA analysis of Spur Gear // International Journal of Current Engineering and Technology December2013. Vol.3, No.5,.
9. Putti SrinivasRao, NadipalliSriraj, and Mohammad Farookh. Contact stress analysis of spur gear for different materials using ANSYS and Hertz equation // International journal of Modern Studies in Mechanical Engineering. June 2015.Vol.1, Issue.1.
10. Utkarsh M Desai, Dhaval A Patel. Modeling and stress analysis of composite material for spur gear under static loading condition // ISSN, 2015. Vol.1, Issue.2.
11. Mohammad Jebran Khan, Arunish Mangla, and Sajad Hussain Din. Contact stress analysis of stainless steel spur gears using FEA analysis and comparision with theoretical results using hertz theory // International Journal of Engineering Research & Applications. April 2015.Vol.5, Issue.4.
12. GOST 21354—87. Предачи зубчатые цилиндрические эвольвентные внешнего зацепления, расчет на прочность. © Издательство стандартов, 1988 г.