University of Banja Luka
Faculty of Mechanical Engineering
DEMI 2017
13th International Conference on Accomplishments
in Mechanical and Industrial Engineering

CALCULATION OF STRESS STATE OF GEAR MADE OF COMPOSITE MATERIALS

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Summary: Stress state of composite gear is very relevant and interesting topic for researchers due to their increasing use, especially in the automotive industry. In recent years, great progress has been made in this area. The gears are usually made of steel, but the progress of materials science make tendency that gears are more often made of material less weight. Reducing weight of mechanical transmission is often the aim of constructors and implementation of composites became very attractive to car designers because of their specific characteristics. In this paper, using *Ansys* program, is made analysis of the stress-strain state of gear. The results obtained by software were compared with the results obtained by analytic, and thus confirmed the credibility of the calculation. With examination on the same model of conical gear pair made of composite materials, it was concluded about the behavior of composite materials and their stress state.
Key words: gears, composites, stress, Ansys

1. INTRODUCTION

Modern mechanical constructions often require special materials, shapes and properties that can fulfil the requirements in difficult operating conditions, such as increased power, pressure, temperature, speed, impact, vibration, etc. There is a growing need for materials that have excellent mechanical properties (high resistance and modulus of elasticity), low weight and cost, which should be as low as possible. The composite is a mix of two or more materials, which aims to obtain a new material with a number of advantageous properties.

By applying composite for gear manufacturing it is obtained a number of advantages compared to steel gears. The advantages of the composite gear are as follows: a relatively small weight, low production costs, noise reduction, reduction of production time, the production method of injection molding with high accuracy of dimensions, the ability to work without lubrication, corrosion resistance.

Usage of composite gears is a relatively new area of application in industry, so

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still the testing is performing on composite materials that shows the best results when applying. Numerous authors have in their papers have worked with this issue.

Polymer gears used in power and motion transmission work under different loads and speeds. Mechanical properties of the polymers are severely influenced by the loading rate compared with the metals. Performance of polymer base gears at different gear rotational speeds is reported in this paper [1]. Injection molded unreinforced Nylon 6 and 20% short glass fiber reinforced Nylon 6 spur gears were tested at various speeds and torque levels in a power absorption type gear test rig. At all the investigated gear speeds, glass fiber reinforced Nylon 6 gears shows superior performance over unreinforced Nylon 6 gears due its superior mechanical strength and resistance to thermal deformation.

In the paper [2] research has been performed about gear working conditions made of different polymer materials, in meshing with the metal gears and by the application of various coatings. The best results could be achieved by coating of PTFE.

In the paper [3] are shown the test results of the polyamide with 5%, 10% and 15% glass fiber. A comparative analysis of the test results and conclusions based on the results tix is presented. The results show that the usage of polyamide with 15% glass fibers better than the 5% polyamide with glass fiber.

Polymer based gears replace metal gears in many light duty power and/or motion transmission applications due to their noiseless operation even under unlubricated conditions. In paper [4] dynamic mechanical analysis carried out on unreinforced Nylon 6/6, 20% short glass and 20% carbon fiber reinforced Nylon 6/6 gear materials indicates the reduction of damping factor due to the incorporation of fibers. Injection molded spur gears made of unreinforced and reinforced materials were tested for durability in a power absorption type gear test rig. Test results indicate that the reinforced gears generate more gear mesh noise than unreinforced gears.

The possible reason of the sudden increase in wear rate is due to the gear operating temperature reaching the material melting point under the critical load condition. Through extensive experimental investigations and modelling on gear surface temperature variations, a general relation has been built up between gear surface temperature and gear load capacity. The method has been related to test results under different operating ambient temperature and gear geometries [5].

2. THE CALCULATION OF STRESS AND DEFORMATION OF STEEL GEARS USING FINITE ELEMENT METHOD

The finite element method is a modern numerical method used for the design and calculation of machine construction with the application of computers. With this method, as opposed to analytical, can be dealt with most complex problems, taking almost realistic boundary conditions, complex geometric shapes and others.

Calculation of bevel gear stress is made in the software package *Ansys* 16.2. Figure 1 shows the appearance of the gears mode with generated finite element mesh.

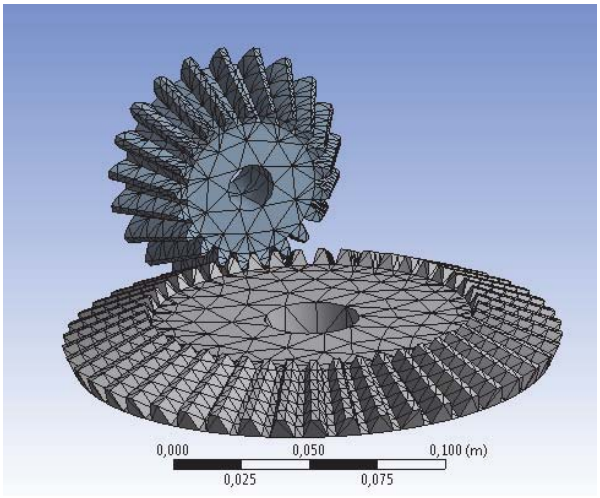


Fig. 1 *Gears model with generated FEM mesh*

When all the necessary conditions are defined (loads and constraints) by clicking Solve, runs the analysis. Figure 2 shows the value of the stress on the side of the teeth, and Figure 3 shows the stress value of the tooth root.

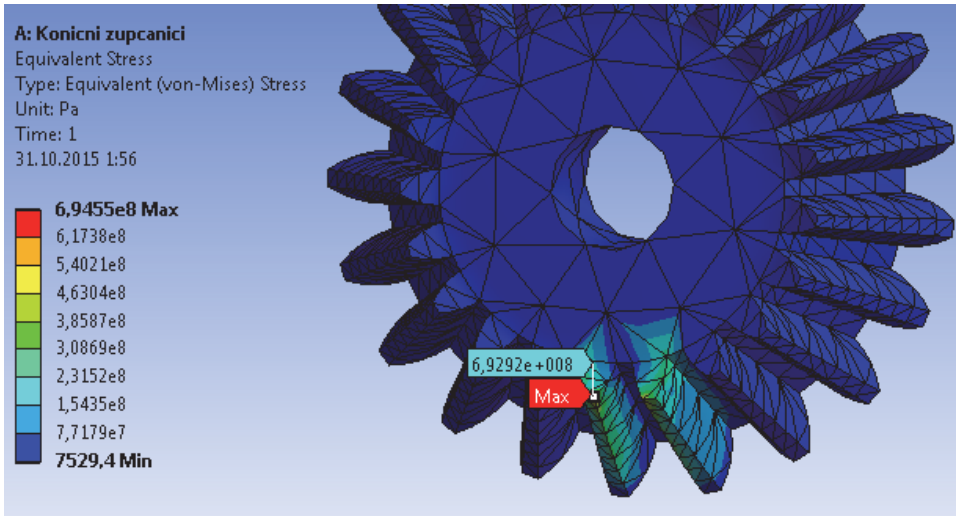


Fig. 2 *Stress on the side of the pinion teeth*

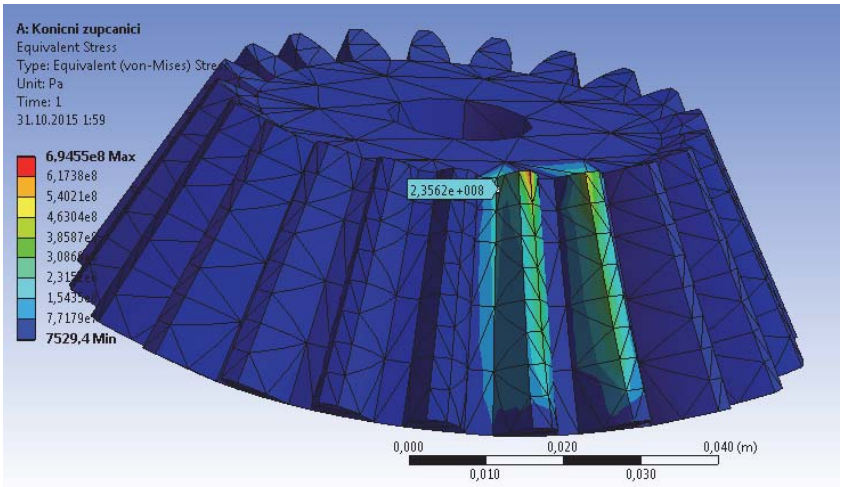


Fig. 3 *The stress at the root of teeth of the pinion*

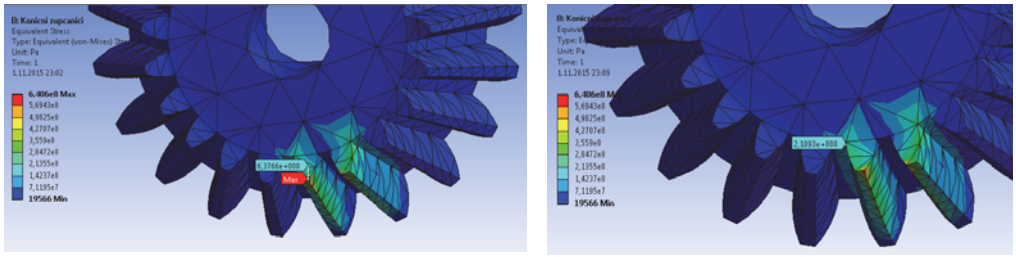
Thus obtained stress value on the side and in the teeth root were compared with the values of stress obtained analytically using software *Autodesk Inventor*. The resulting deviation is shown in Table 1, show the correctness of the formed model which is made in the software package *Ansys*, so this model adopts the test gear made of composite materials.

Table 1 *Stress values comparison*

	Analytical calculation	Numerical calculation	Deviation
Stress on the teeth side, MPa	679	692	1,91 %
Stress on teeth root, MPa	219	235	7,30 %

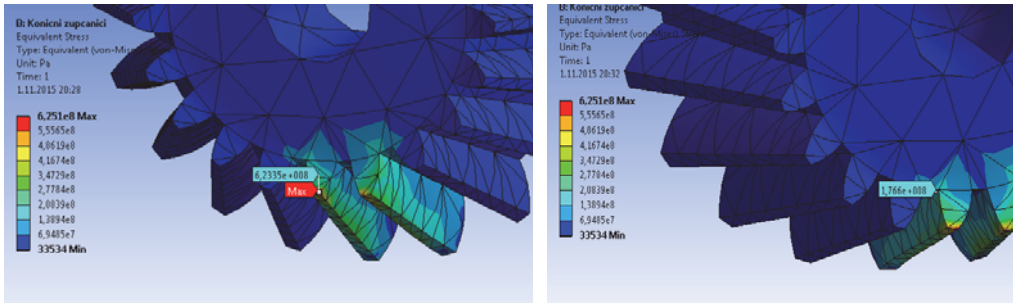
3. CALCULATION OF COMPOSITE GEAR STRESS AND STRAIN USING FINITE ELEMENT METHOD

At the same load and the same model of the gear will be observed behavior of several types of composite materials (Glass filled polyamide and Epoxy carbon UD).



(a) (b)

Fig. 4 *Stress on teeth side (a) and in teeth root (b) of the pinon made of Glass filled polyamide*



(a) (b)

Fig. 5 *Stress on teeth side (a) and in teeth root (b) of the pinon made of Epoxy carbon UD*

The results of stress analyzed for three materials: stainless steel, glass-epoxy polyamide and carbon are given in Table 2.

Table 2 *Stress values comparison*

	Steel	Glass polyamide	Epoxy carbon
Stress on the teeth side, MPa	694	640	625
Stress on teeth root, MPa	235	210	176

By analyzing the results which are presented in Table 2 it is concluded that the stresses on the teeth of the gear made of selected composite material lower in comparison with steel.

4. CONCLUSION

The analysis of the results is obtained by examining the model of bevel gears using *Ansys* 16.2. The obtained results have confirmed the hypothesis that the usage of modern composite materials is possible to reduce the stresses on the sides and at the

root of the gear teeth. Considerations about the viability of such structural solutions are not carried out, but the analysis is done from the point of considering stress conditions on gears.

The conclusion is that composite materials can be an alternative to steel gears while achieving reduction in mass compared to steel gears, but with a higher price.

Acknowledgement

This investigation is a part of the project TR 33015 of Technological Development of the Republic of Serbia and the project III 42006 of Integral and Interdisciplinary investigations of the Republic of Serbia. We would like to thank to the Ministry of Education and Science of Republic of Serbia for the financial support during this investigation.

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