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DESIGN OF BODY WHEEL SHAPE TO IMPROVE TEETH STIFFNESS FOR GEARBOX OF MECHATRONIC SYSTEMS

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Abstract: The most important component of your drive systems of mechatronic units are geared systems. Prospective application of highly accurate transfers it can be examined by the need to adapt to our own design, size and the minimum weight transfer. It is anticipated construction material so flow density, high stiffness, reliability, positioning, control. Increasing performance and improving load machines with gear unit leads to increase the technical level of machines. This process is often at the cost of degradation of the environment. One of the factors that aggravate environmental is a noise. Periodic changes the stiffness of the tooth during meshing in gear drives mainly affects of the noise in the transfer. The work is devoted to the analysis of influence of the body wheel shape on the tooth stiffness. The problem is solved for spur gears. As the basis for calculating the tooth stiffness are results of teeth deformation. The teeth deformation has be solution problem by finite element method.

1 Introduction

Gear wheels became a symbol of engineering. They are the basic element, through which transmission and transformation of mechanical power and movement are implemented in machines [1-3]. They are one of the most complicated mechanical components from the theoretical, construction and production viewpoint. The machines and machineries with gear transmission are very popular and draw sufficient attention. The weight reduction of the construction machines and engine plants as well as increasing of their efficiency and productivity, are all part of the important task in the area of the construction, technology and research workers must accomplish them [4].

2 Definition of tooth stiffness

Deformation of teeth is usually expressed quantitatively as a teeth stiffness during by gear mesh [5]. In general, stiffness defined as the ratio of load to deformation. The stiffness of the tooth is defined as the force per unit width, which is necessary for the deformation about 1μm [6-8]. Theoretical determination of teeth deformation of involute gears is difficult, because the tooth profile is consists of involute and smooth filet. The previous experimental procedures were based on the static deformation measurements gearing loaded constant force, or seismic measurement deviations as you turn. But it requires the construction of a suitable model and use of appropriate machinery, given the limited value of deformation quality measurement technology. The matter in question is thus preferable to solve finite element, which is one of the most widely used numerical methods. The tooth deformation of spur gears is not constant for all examined teeth of gears. The deformation of the teeth depends on the shape of the teeth, thus the basic parameters of the gearing and on the shape and construction of the body wheel and the wheel load.

As has been said, the teeth of the gear wheels are deformed due to load. This is the cause of some negative but also positive consequences. Therefore, the knowledge of the deformation properties of the teeth is very important [9].The theoretical determination of the teeth deformation is difficult due to the complex shape of the gear teeth. In recent years, the question of teeth deformation has been solved using modern methods of calculation, for example by a finite element method. The finite element method is used to determine the teeth deformation [11-12]. We will focus on the value of the total deformation in the direction of action forces (Figure 3).On the basis of the teeth deformation, the stiffness of the teeth is calculated. In general the teeth stiffness c is defined by equation (1):

$$c = \frac{w}{\delta} \qquad (1)$$

where c – tooth stiffness [N/mm.μm],
w – load across the width of the teeth [N/mm],
δ – tooth deformation [μm].

The teeth stiffness values are the basis for assessing the suitability of design of the wheels of mechatronic system in this paper.

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3 Design of various types of gear wheels

Achieving the smallest weight of the spur gear wheel is the designer's effort in designing the shape of a large gear wheel body. However, the reduction of the load-bearing cross-sections is usually limited by the requirement for sufficient stiffness of the bodies. In the case of gears it is gear mesh stiffness.

Large-dimensional gear wheels can be made as monolithic one, the most commonly are a forged and cast gear wheels. Spur gears with a diameter of 200 to 500mm are produce of forged blanks most commonly. Larger spur gears with a diameter of over 500mm may be produce as a cast blanks. But striving to improve the design of the gears, aimed at reducing the dimensions and weight, has be led to the used of gears with thin-walled gear rim and with thin gear rim. Figure 1 shows an example of design a forged and cast body of spur gear wheel.

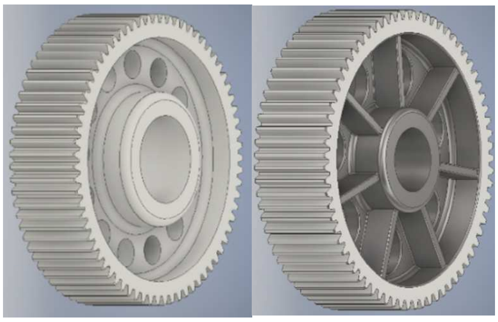

Figure 1 Design of body gear wheel

The wheel rim thickness (s_R) and wheel web thickness (b_S) (in Figure 2) are important parameters which influence of weight of gear wheel. In the next section, the paper will focus on the influence of wheel rim and web parameters on the tooth stiffness of spur gears.

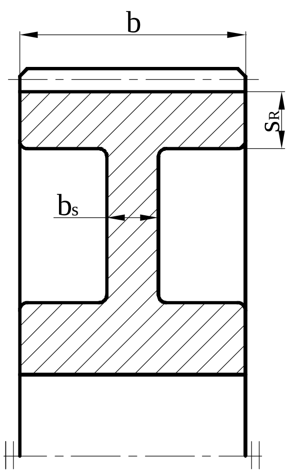

Figure 2 Design of gear wheel

4 Influence of the shape of body gears wheel on the tooth stiffness

Achieving The impact of the rim thickness (value s_R in Figure 2) on the deformation and stiffness of the tooth will be determined on the spur gear with a number of teeth of z=61 and a module m_n=4mm and a tooth width b=80mm.

Will be examined the tooth stiffness under load F=5000 N, if the if the force is applied to the head of the tooth (the largest bend) according to Figure 3.

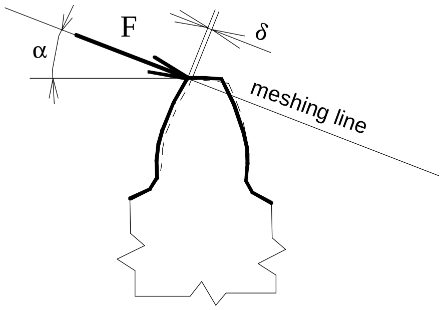

Figure 3 Deformation of tooth

Will be examined the tooth stiffness under load F=5000 N, if the if the force is applied to the head of the tooth (the largest bend) according to Figure 3. The thickness of the wheel rim is changed from the value s_R=1.75m_n (2.5m_n, 3.5m_n, 5m_n, 8m_n and full wheel) to the full body of the wheel. These results are determined by the finite element method and are processed in the graph in Figure 4.

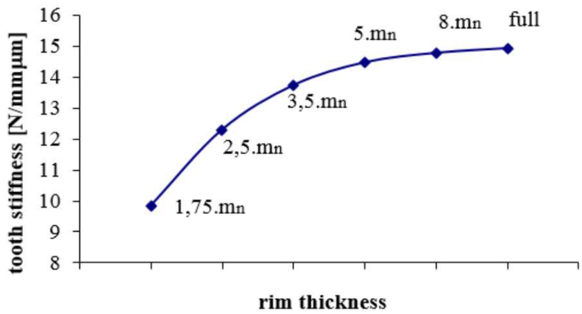

Figure 4 Influence of wheel rim on the tooth stiffness

As the results show, decreasing the thickness of the rim wheel is increases the tooth deformation and the tooth stiffness is decreases. The minimum permissible thickness of the wheel rim according to [10] is a s_R = 3.5m_n, where m_n is a modul of the gear wheel. Thickness of wheel rim less than value 3.5 m_n has more affects to the tooth deformation and stiffness. Thickness of wheel rim bigger than value 3.5 m_n has smaller affects to the teeth deformation and stiffness, as show in the Figure 4.

The impact of the rub thickness (value b_S-Figure 2) on the tooth stiffness will be determined on the spur gear with a number of teeth of z=61 and a module m_n=4mm and a

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tooth width b=80mm, the value of wheel rim is s_R=22mm. The web is located at the center of the gear wheel width and its thickness will change from 10 mm to the 80 mm, when it is a full gear wheel without a web. The force is applied to the head of the tooth (the largest bend) according to Figure 3 and the value of load across the width of the tooth is a w=40N/mm.

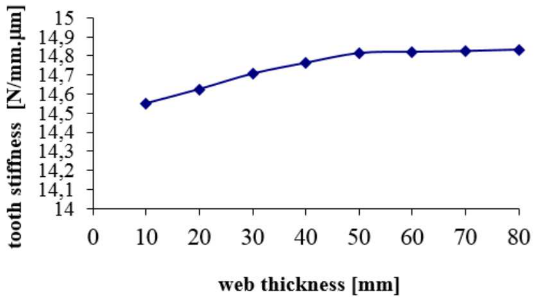

Figure 5 Influence of wheel web on the tooth stiffness

The tooth deformation is reduced and the tooth stiffness is expanded, due to the increase in the thickness of the wheel web located at the center of the gearing width, it is show in Figure 5. This change in tooth deformation and tooth stiffness is more pronounced to the first half of gearing width.

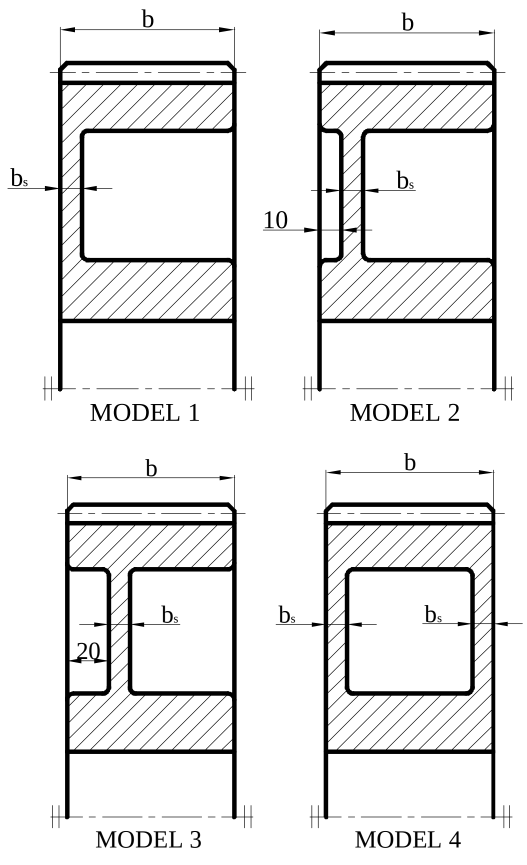

Figure 6 The locality of wheel web

The influence of the wheel web (value b_S-Figure 2) localization on the tooth stiffness will be determined on the spur gear with a number of teeth of z=61 and a module m_n=4mm and a tooth width b=80mm, the value of wheel rim is s_R=22mm.

The wheel rub thickness is b_S=10mm and its locality varies according to Figure 6.

The results of the maximum tooth deformation examined at the loading point, if the force acts on the tip of the tooth (Figure 3), for wheels web with different station locations, according to the models 01 to 04 (Figure 6), are shown in the Figure 7. The value of the tooth deformation in the place of loading we consider the second highest value.

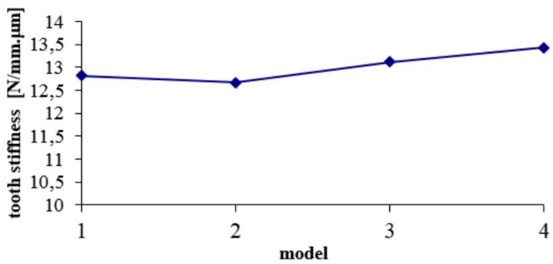

Figure 7 Influence of wheel web localization on the tooth stiffness

The minimum tooth deformation, the maximum tooth stiffness, is for the gear whit two wheel web. These wheel webs are located at the edges of the wheel width. This is due to the supportive effect of wheel web. The wheel web placement in generally is affects the teeth deformation as well as the teeth stiffness over the width of the spur gear.

5 Conclusions

Development of the modern machinery and means of production is characterized by steadily increasing performance factors in decreasing the weight of the device. Lightening of body wheel gears has affects on the deformation and stiffness of the teeth. Teeth stiffness is decreases with the decrease in thickness of the wheel rim. Teeth stiffness is not constant even after the width of tooth. If the ends of mesh contact line identic of the edge of the teeth, the teeth stiffness is less on this locality. The teeth deformation is reduced and the teeth stiffness is expanded, due to the increase in the thickness of the wheel web located at the center of the gearing width. The localization of wheel web has a influence of the teeth stiffness. Gear teeth are deformed due to the load. Recently, at ever faster evolving computer technology, the available literature, we can meet with modern numerical methods, such as finite element method (FEM), which can serve as one of the methods for the determination of teeth deformation of gearing.

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References

[1] BATSCH, M.: Surface strength of novikovcovexo-concave gear, *Scientific Journal of Silesian University of Technology. SeriesTransport*, Vol. 90, p. 17-24, 2016.

[2] COOLEY, Ch. G., LIU, Ch., DAI, X., PARKER, R. G.: Gear tooth mesh stiffness: A comparison of calculation approaches, *Mechanism and Machine Theory*, Vol. 105, p. 540-553, 2016.

[3] CZECH, P.: Diagnosis of Industrial Gearboxes Condition By Vibration and Time-Frequency, Scale-Frequency, Frequency-Frequency Analysis. *Metalurgija*, Vol. 51, No. 4, p. 521-524, 2012.

[4] SATIEPKOVÁ, A. et al: Utilizing of sensitivity analysis in preparation of optimizing procedure, *Transport*, Vol. 76, p. 32-38, 2012.

[5] MADEJ, H., CZECH, P.: Discrete Wavelet Transform and Probabilistic Neural Network in IC Engine Fault Diagnosis, *Eksploatacja I niezawodnosc- maintenance and reliability*, Vol. 4, p. 47-54, 2010.

[6] MEDVECKÁ-BEŇOVÁ, S.: Influence of the face width and length of contact on teeth deformation and stiffness, *Scientific Journal of Silesian University of Technology: Series Transport*, Vol. 91, p. 99-106, 2016.

[7] RINCON, A. F., VIADERO, F., IGLESIAS, M., GARCÍA, P., SANCIBRIAN, R.: A model for the study of meshing stiffness in spur gear transmissions, *Mechanism and Machine Theory*, Vol. 61, p. 30-58, 2013.

[8] KURYŁO, P.: Rozkład naprężeń w warstwie wierzchniej napawanych odlewów żeliwnych Proizvodstvo, *Tehnologiâ, Ekologiâ*, Vol. 10, p. 573-584, 2007. (Original in Polish)

[9] KELEMEN, M., KELEMENOVÁ, T., JEZNÝ, J.: Four legged robot with feedback control of legs motion, *Bulletin of Applied Mechanics*, Vol. 4, No. 16, p. 115-118, 2008.

[10] NOGA, S., MARKOWSKI, T., BOGACZ, R.: Method of determining thenormal modes of toothed gears with complex geometry, *Scientific Journal of Silesian University of Technology, SeriesTransport*, Vol. 89, p.119-127, 2015.

[11] KAŠŠAY, P.: Comparison of pneumatic flexible shaft coupling static load characteristics obtained experimentally and by calculation, *Scientific Journal of Silesian University of Technology. SeriesTransport*, Vol. 85, No. 1925, p.57-65, 2014.

[12] URBANSKÝ, M.: Theoretic and Experimental Determination of the Flow Resistance Coefficient at Gaseous Medium Flow into and out of the Pneumatic Coupling, *Scientific Journal of Silesian University of Technology. SeriesTransport*, Vol. 85, No. 1925, p.119-125, 2014.

[13] KELEMEN, M., VIRGALA, I., FRANKOVSKÝ, P. et al.: Amplifying system for actuator displacement, *International Journal of Applied Engineering Research*, Vol. 11, No. 15, p. 8402-8407, 2016.

[14] SAPIETA, M., DEKÝŠ, V., PASTOREK, P.: Using of activ thermography and lock-in method with ultrasound exication for detection of material defect, *Zeszyty naukowe Politechniki Śląskiej*, Vol. 84, No. 1907, p. 119-124, 2014.

[15] CZECH, P., WOJNAR, G., WARCZEK, J.: Diagnozowanie uszkodzeń wtryskiwaczy w silnikach spalinowych pojazdów przy użyciu analizy bispektrum i radialnych sieci neuronowych, *Logistyka*, No. 3, p. 1181-1187, 2013. (Original in Polish)

[16] SIKA, G., VELEX, P.: Analytical and numerical analysis of gears in the presence of engine acyclism, *Journal of Mechanical Design - the ASME*, Vol. 130, p. 1–6, 2008.

[17] TERTEL, E., KURYŁO, P., PAPACZ, W.: Parallelepiped sandwich shell-searching for the optimal geometric parameters, *Applied Mechanics and Materials, Trans Tech Publications*, p. 170-174, 2014.

[18] PIVARČIOVÁ, E., BOŽEK, P., TURYGIN, Y., ZAJAČKO, I., SHCHENYATSKY, A., VÁCLAV, Š., CÍSAR, M., GEMELA, B.: Analysis of control and correction options of mobile robot trajectory by an inertial navigation system, *International Journal of Advanced Robotic Systems*, Vol. 15, No.1, 2018.

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