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Influence of the Body Wheel Shape on the Tooth Stiffness

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Introduction

At present it is still higher demands on machine parameters. This is manifested by the increasing load and increasing the speed of individual parts of machine [1, 3]. All while of increasing requirements for performance, accuracy, lifetime reliability of the machinery itself. It is necessary to consider the action of internal and external load and the dynamic processes in machines. 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.

Tooth Stiffness of spur gears

Deformation of teeth is usually expressed quantitatively as a teeth stiffness during by gear mesh [4]. 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 [5, 9]. During the mesh cycle, the stiffness of the teeth is changes, it is mainly due to the change arm bend. Basically the mesh stiffness of a given gear pair depends on several parameters, particulartly the load and the rotational position of the gears. Provided we assume linear-elastic material properties, which is reasonable for metal gears, the contact stiffness varies with the load (as the contact zone gets larger and thus stiffer with higher contact forces) where as the other portions, like tooth bending a.o. are constant. But the stiffness definitely depends on the point of force application on the tooth flank and on the contact ratio (i.e. how many teeth are sharing the load at a given mesh position) and thus on the angular position of the gears. These variations are periodic.

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 [6, 8]. 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. We will focus on the value of the total deformation in the direction of action forces (Fig. 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):

$$c = \frac{w}{\delta} \tag{1}$$

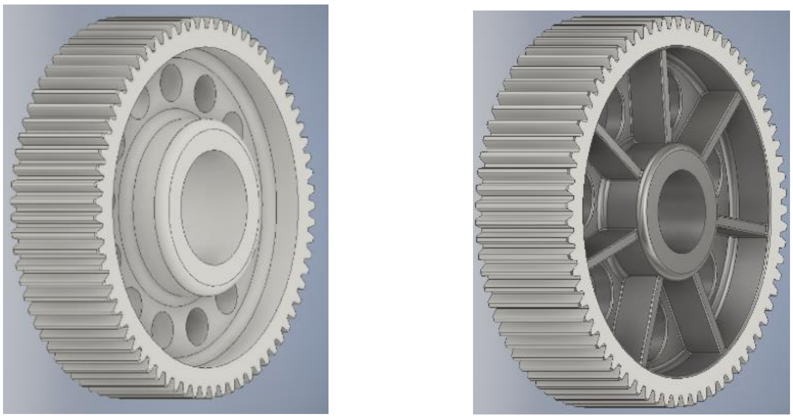
where c – tooth stiffness [N/mm.μm],
w – load across the width of the teeth [N/mm],
δ – tooth deformation [μm].

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

Construction of large-dimensional 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 a 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. Fig.1 shows an example of design a forged and cast body of spur gear wheel.



a) b)

Fig. 1 Design of body gear wheel of a) forged and b) cast blanks of the spur gears

The wheel rim thickness (s_R) and wheel web thickness (b_S) 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.

Influence of the wheel rim thickness on the tooth stiffness

The impact of the rim thickness (value s_R in Fig.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.

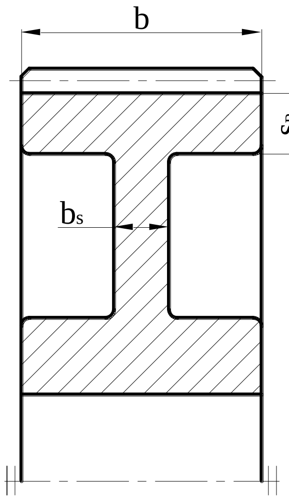


Fig. 2 Design of gear wheel

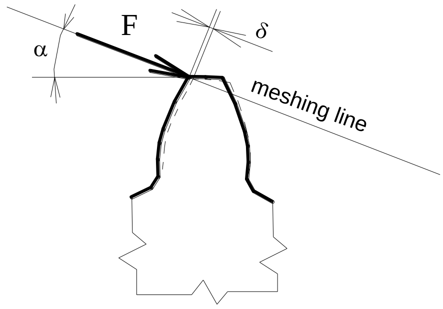


Fig. 3 Deformation of tooth

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 Fig.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 Fig.4.

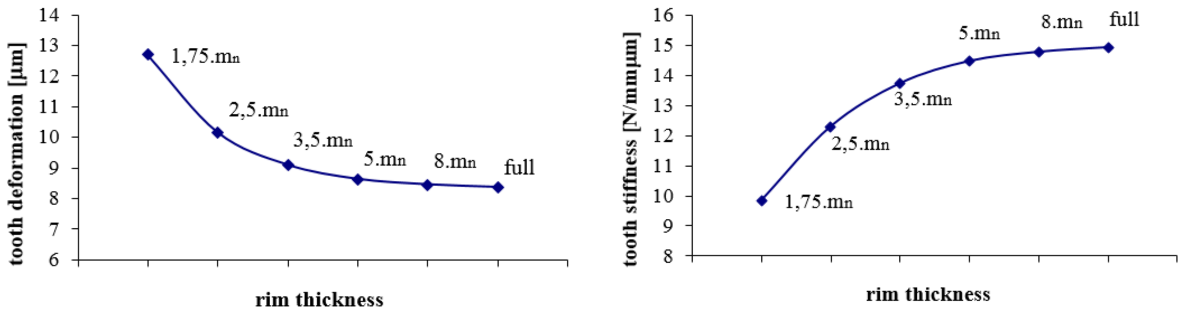


Fig. 4 Influence of wheel rim on the tooth deformation and stiffness, if z=61, m_n=4mm, b=80mm, F =5000 N

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 Fig.4.

Influence of the wheel web thickness on the tooth stiffness.

The impact of the rub thickness (value b_S - Fig.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 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 Fig.3 and the value of load across the width of the tooth is a w=40N/mm.

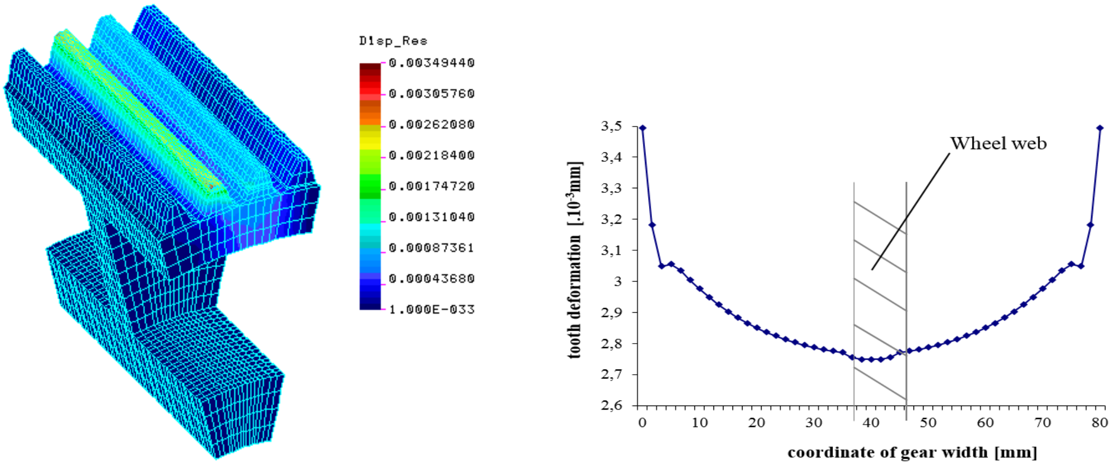


Fig. 5 Example of the tooth deformation on the spur gear with z=61, m_n=4mm, b=80mm, w=40N/mm, b_S=10mm solution by FEM

The results of the deformation distribution along the gear wheel width and solution by finite element method are shown in Fig. 5 and for the above mentioned gear wheel model. In this figure is the local influence of the tooth deformation with is distribution on the gear width. The lesser value on tooth deformation is in the locality with wheel web.

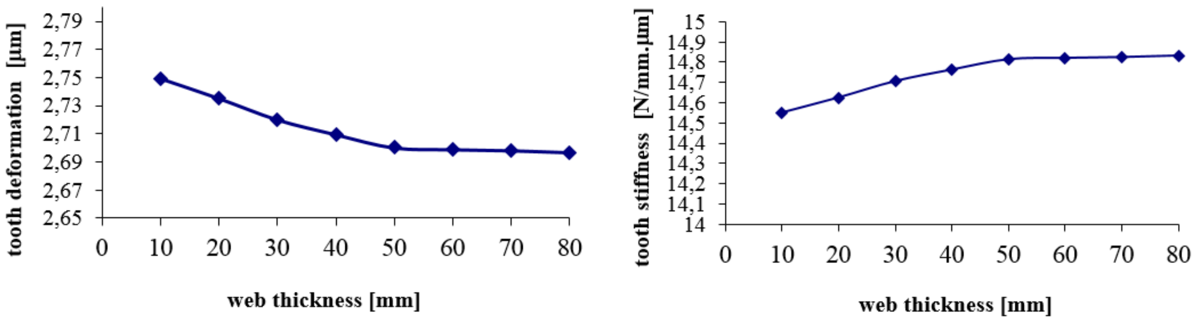


Fig. 6 Influence of wheel web on the tooth deformation and tooth stiffness, if z=61, m_n=4mm, b=80mm, s_R=22mm, w=40N/mm

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 Fig. 6. This change in tooth deformation and tooth stiffness is more pronounced to the first half of gearing width.

Influence of the wheel web localization on the tooth stiffness

The influence of the wheel web (value b_S - Fig.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 force is applied to the head of the tooth (the largest bend) according to Fig.3 and the value of load across the width of the teeth is a w=40N/mm. The wheel rub thickness is b_S=10mm and its locality varies according to Fig.7.

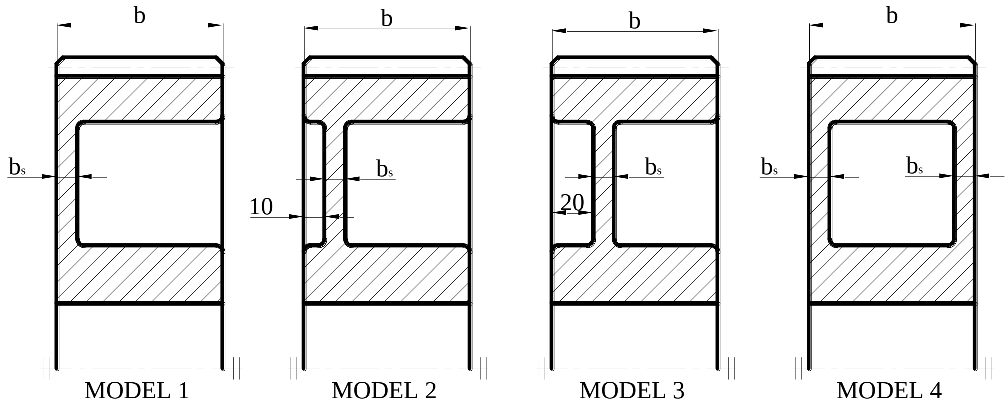


Fig. 7The locality of wheel web

Example of the tooth deformation on the spur gear for spur gear with wheel web localization as model 2 (Fig. 7), solution by finite element method is show in Fig.8. The results of the tooth deformation are solution by along the gear wheel width.

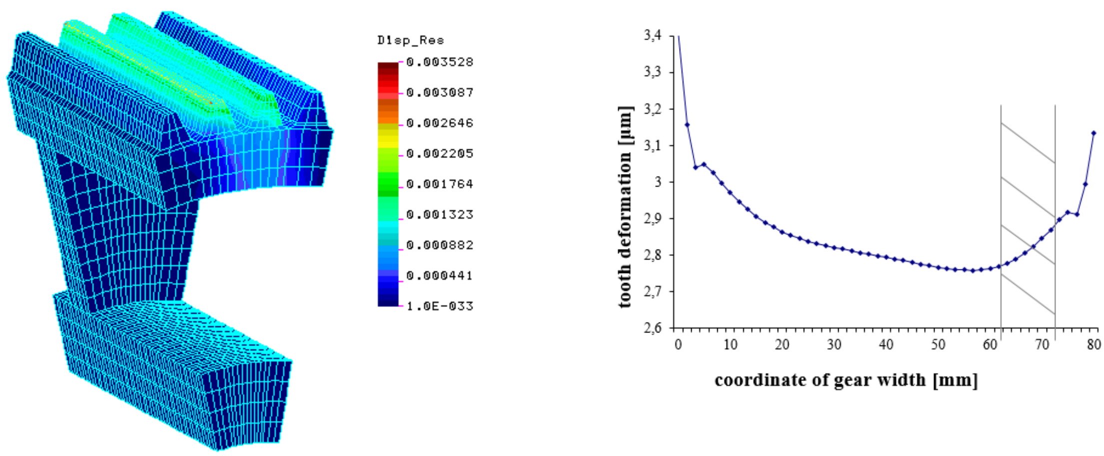


Fig. 8 Example of the tooth deformation on the spur gear with z=61, m_n=4mm, b=80mm, w=40N/mm, b_S=10mm solution by FEM, model 2

The results of the maximum tooth deformation examined at the loading point, if the force acts on the tip of the tooth (Fig. 3), for wheels web with different station locations, according to the models 01 to 04 (Fig.7), are shown in the Fig.9. The value of the tooth deformation in the place of loading we consider the second highest value.

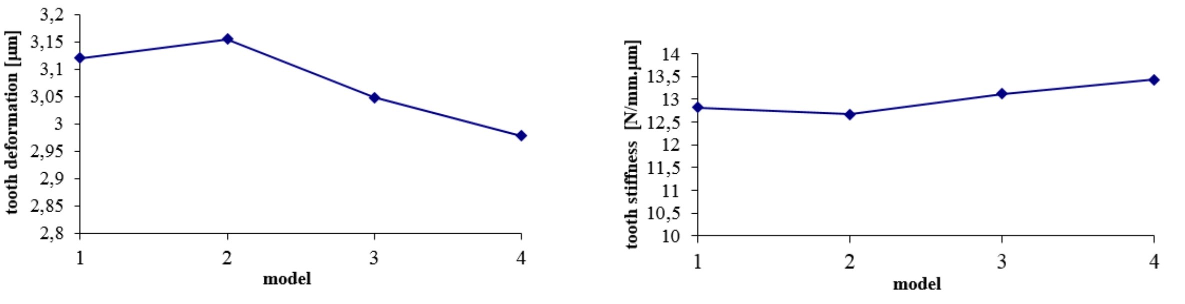


Fig. 9 Influence of wheel web localization on the tooth deformation and stiffness, if z=61, m_n=4mm, b=80mm, s_R=22mm, w=40N/mm, for model 1, 2, 3 and 4

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.

Conclusions

Development of the modern machinery and means of production is characterized by steadily increasing performance factors in decreasing the weight of the device. It is a feature of the design for choice of the shape of the body larger gear. 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.

Acknowledgement

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