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INFLUENCE OF THE FACE WIDTH AND LENGTH OF CONTACT ON TEETH DEFORMATION AND STIFFNESS

Summary. Gear teeth are deformed due to load. Recently, given the increasingly evolving computer technology, supported by the available literature, we have modern numerical methods at our disposal, such as the finite element method (FEM), which serves as one of the methods for the determination of teeth deformation in the gearing. This paper mainly deals with deformation distribution across the teeth's face width in relation to the load width of the teeth when meshing occurs. The solution for teeth deformation of spur gears is provided by the FEM.
Keywords: spur gear, deformation of teeth, face width, finite element method, stiffness

1. INTRODUCTION

The theoretical determination of teeth deformation in involute gears is difficult because the teeth profile consists of an involute and smooth filet. Previous experimental procedures were based on the static deformation measurements of the gearing's loaded constant force or the seismic measurement deviations when turns are carried out. However, such procedures require the construction of a suitable model and the use of appropriate machinery, given the limited value of deformation quality measurement technology. The FEM, therefore, is

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preferable in terms of solving the matter in question, given that it is one of the most widely used numerical methods. Teeth deformation in spur gears is not consistent for all examined gear teeth. Such deformation depends on the shape of the teeth and, in turn, the basic parameters of the gearing, as well as the shape and construction of the body wheel and the wheel load. This paper mainly deals with teeth deformation with regard to the face width, with the FEM presented as the solution to this problem.

2. DEFORMATION AND STIFFNESS IN THE TEETH OF SPUR GEAR

As previously stated, the FEM is a solution for the deformation of teeth when meshing occurs. We will focus on the value of the total deformation in the direction of action forces (Fig. 1). To determine the deformation of the gearing under a load, it is necessary to be aware of the apportionment of the load on each gearing pair when two pairs mesh. Firstly, let us consider the simplest, ideal load apportionment, which is when two pairs meshing and the load is divided by half for each pair of teeth involved in the meshing. Exercises to calculate the gearing strength, shafts, gear wheels etc. involve a combined load, which is replaced by lonely forces (Fig. 2). In our case, we will examine the problematic in hand with regard to deformation in the width of the teeth.

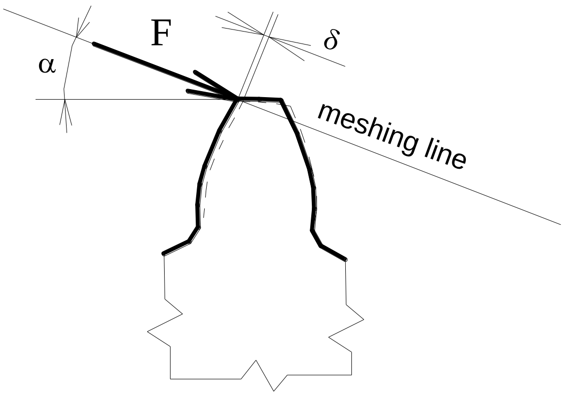


Fig. 1. Teeth deformation of teeth

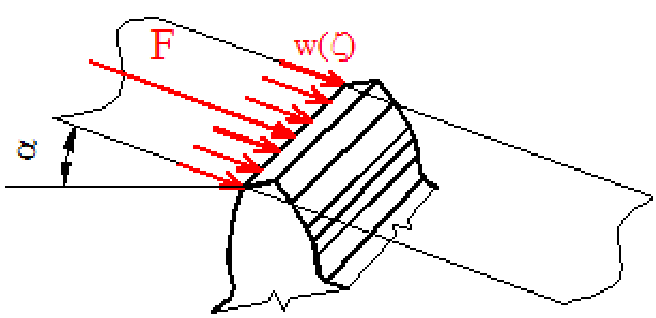


Fig. 2. Explanation of the load across the width of a single force

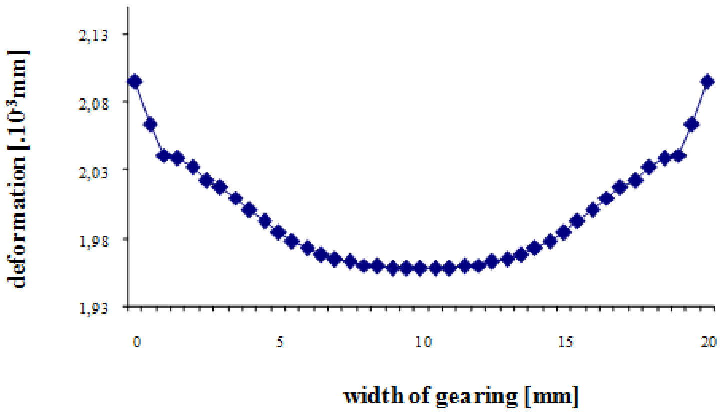
One of the ways to calculate teeth stiffness is by analysing the total gearing deformation as determined by the FEM. In general, the resulting stiffness c is defined by Equation (1):

$$c = \frac{w}{\delta}\ , \qquad [\mathrm{N/mm.\mu m}] \qquad (1)$$

where w is the load across the width of the teeth [N/mm], while δ is the resulting deformation [μm].

3. FEM SOLUTION FOR TEETH DEFORMATION AND STIFFNESS

After carrying out an analysis of teeth deformation in the spur gear, in order to evaluate the 3D approach to the FEM, it was found that deformation and stiffness were not constant across the width of the teeth, but change. For the spur gear model used in this example, the number of teeth z=19, the module of teeth m=1mm, the load w=25N/mm (F=500N) and the gearing width b=20mm. Fig. 3 shows the course of the teeth deformation and stiffness, when the spur gear is examined, if the width of the teeth is consistent with the load width. The load is applied as shown in Fig. 1. Under the influence of the free end of the teeth, but without any support effect, there is a change to the beginning and the end of the meshing, while the deformation of teeth expands and the stiffness of teeth reduces.



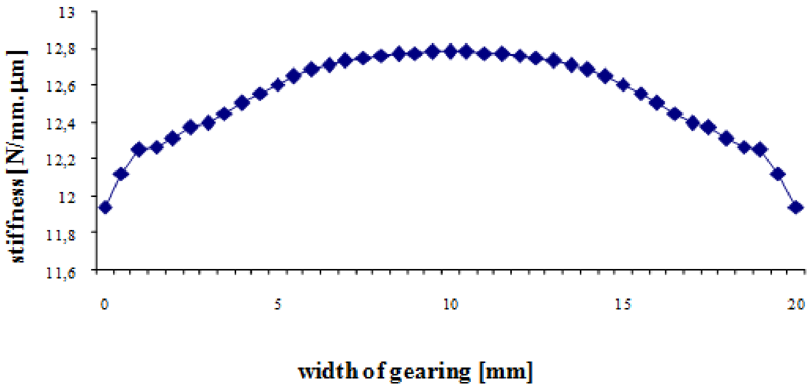


Fig. 3. Teeth deformation and stiffness when the gearing width is consistent with the load width

In practice, we encounter cases where the load width is less than the gearing width. Therefore, let us consider the case where the gearing width gearing remains unchanged (b=20mm), while the load width is reduced on each side, firstly, by 0.5mm (Fig. 4a) and, secondly, by about 2.5mm (Fig. 4b).

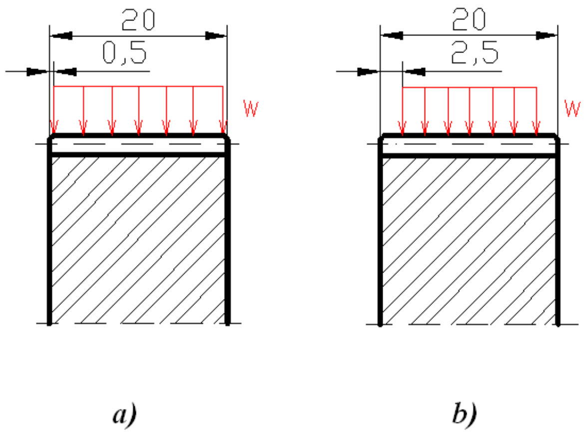


Fig. 4. Load width

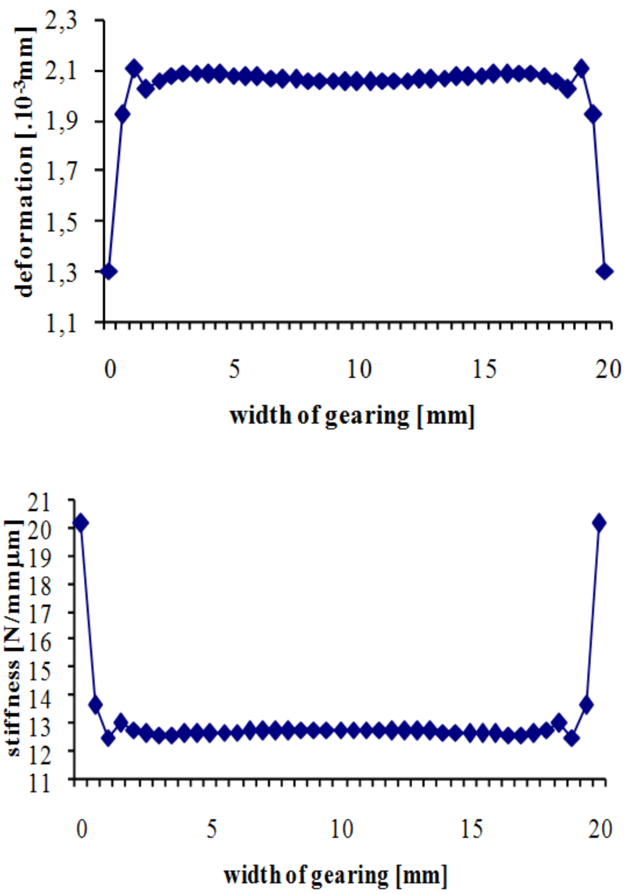


Fig. 5. Teeth deformation and stiffness when the gearing width is not consistent with the load width, as shown in Fig. 4a.

Fig. 5 shows the course of the teeth deformation and stiffness in relation to Fig. 4a. This concerns a spur gear model where the number of teeth z=19, the module of the teeth m=1mm, the load w=26.31579N/mm (F=500N), the gearing width b=20mm and the load width b_w=19mm.

Fig. 6 shows the course of the teeth deformation and stiffness in relation to Fig. 4b. It concerns a spur gear model where the number of teeth z=19, the module of teeth m=1mm, the load w=33.33N/mm (F=500N), the gearing width b=20mm and the load width b_w=15mm.

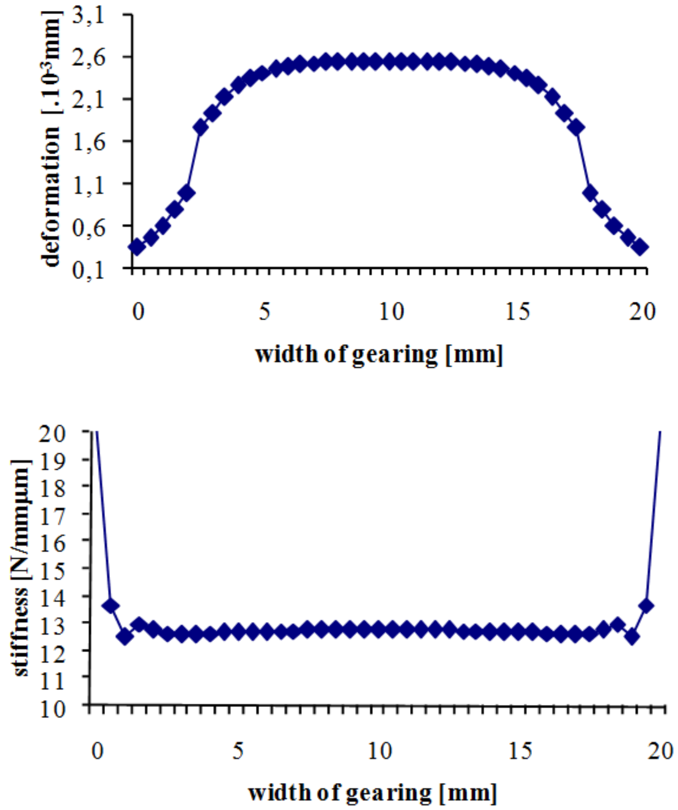


Fig. 6. Teeth deformation and stiffness when the gearing width is not consistent with the load width, as shown in Fig. 4b

According to Fig. 5 and Fig. 6, if the load width is less than the gearing width, the deformation at the edges of the meshing incurs a sharp drop, while the stiffness experiences a sharp increase.

When the course of teeth deformation occurs in which the load width is equal to or less than the gearing width, we can also monitor the effectiveness in addressing teeth deformation by use of the 3D FEM (Fig. 7). When dark red is displayed, this means that the maximum deformation of the teeth along the load width is limited.

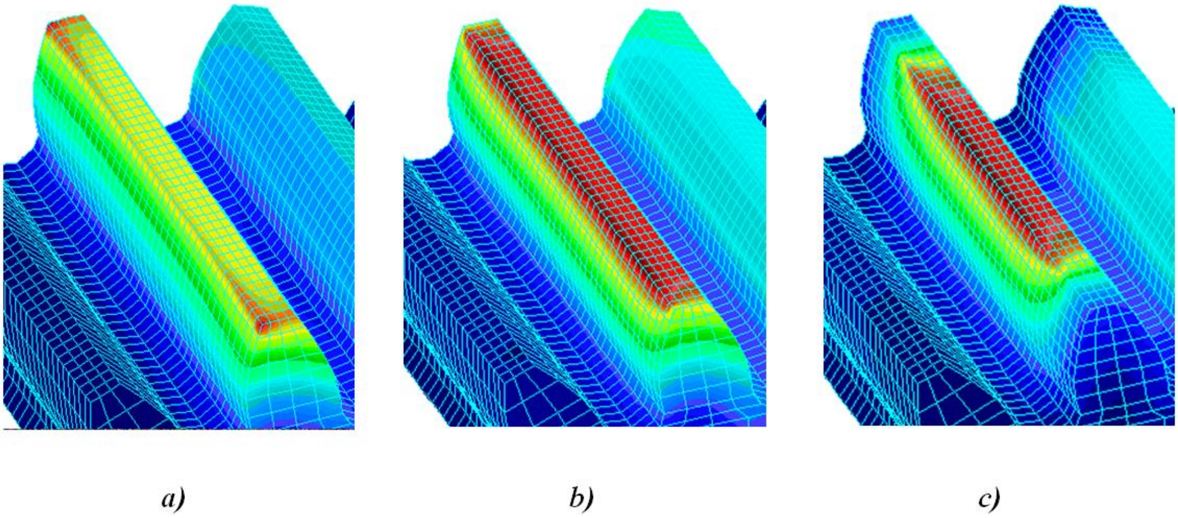


Fig. 7. Teeth deformation solution using the FEM: a) where the gearing width is consistent with the load width; b) where the gearing width is not consistent with the load width, as shown in Fig. 4a; and c) where the gearing width is not consistent with the load width, as shown in Fig. 4b.

It should also be understood that the course of deformation and stiffness across the width of the teeth, when determined at various characteristic points on a line of action, will be different. This is demonstrated in Fig. 8, which concerns a spur gear model where the number of teeth z=19, the module of teeth m=1mm, the load w=33.33N/mm (F=500N), the gearing width b=20mm and the load width b_w=b=20mm.

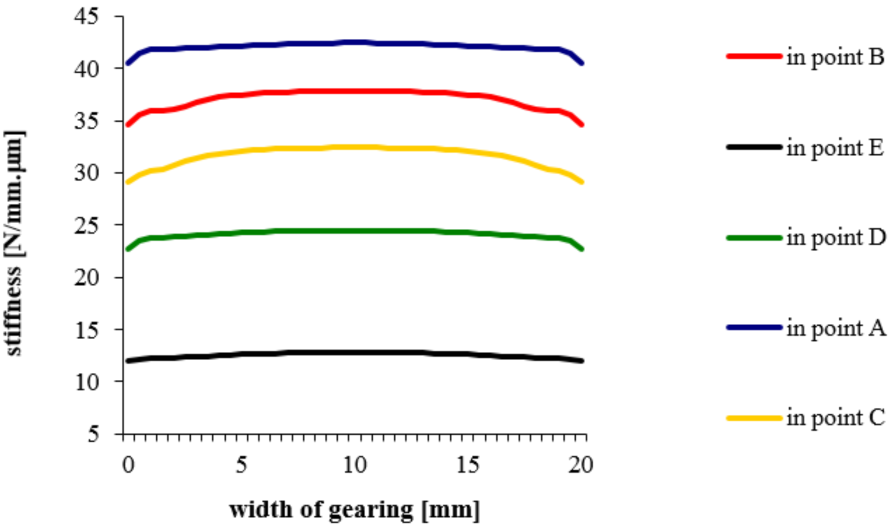


Fig. 8. Teeth stiffness at the characteristic points of contact

The characteristic points of contact are defined in Fig. 9. Points A and E are the so-called external or end points along the AE line of action. Points B and D are the so-called end points of lonely meshing. Point C is a central contact point.

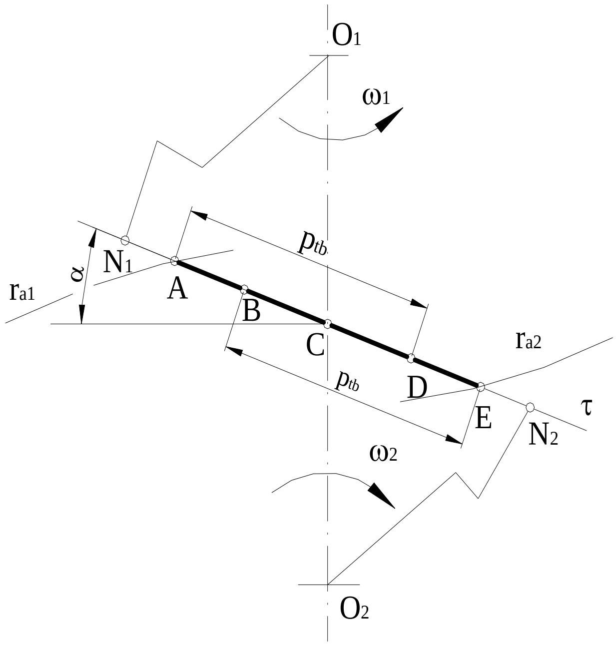


Fig. 9. Characteristic points of contact in the spur gear

It can be seen that teeth stiffness at the characteristic points under the same conditions change.

4. CONCLUSION

It is possible to demonstrate, with great accuracy, teeth deformation along the width of the load on the examined gear teeth by using the FEM. The findings in relation to this deformation may be used to determine the stiffness of the teeth. Periodic changes in stiffness when teeth mesh are caused by changes in the number of pairs of teeth, which also mesh in order to create a significant noise impact on the teeth.

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