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# INFLUENCE OF WEB THICKNESS ON MAXIMUM RIM STRESS

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## ABSTRACT
*The FEM stress calculation has been performed of spur thin-rimmed gear with middle web position, in order to study maximum stress that appears at inner rim surface. The contribution of web thickness to thin rim rigidity and the corresponding variation of maximum equivalent rim stress magnitude and location have been examined, and the influence of rim and web thickness upon maximum rim stress has been compared.*
**Keywords:** thin-rimmed gear, web thickness, rim stress

## 1. INTRODUCTION
The strength evaluation of thin-rimmed gears with complex body consisting of rim, web and hub, has been the issue of great importance owing to the demands on modern gear transmissions. The dimensioning of gear body elements after careful stress analysis is the necessity nowadays, in order to meet greater reliability as well as economic demands.
Intensive research into a state of stress at tooth-root, as critical location for gear failure, in relation to various factors of influence, has not been adequately accompanied by the research into the stress that occurs at gear body elements.
An early experimental work [1] dealing with the effect of web thickness variation on the performance of spur gears, resulted with the conclusion that by reducing the web thickness considerable reduction in weight of material is achieved without sacrificing the quality of performance.
The stress analysis has to be based on reliable prediction of load distribution along the facewidth that results from the modus of such gear structure deformation. Therefore, the research into stress state of gear body elements demands proper geometrical and numerical model. Analytical studies that have been conducted differed in the way the corresponding load distribution is determined, in geometrical model, representing full or partial gear, and in the number of teeth included in the model.
In [2] the stresses of thin- rimmed gear blank with one middle web and two middle webs, at different rim and web locations were determined. Additionally, the attention was devoted to the influence of contact lines errors on the load distribution along the facewidth, for various rigidity of gear body.
For the gear, component of helicopter principal transmission, the stress distribution of web with lightening holes, was studied, in order to evaluate the effects of overstress caused by a reduction in weight in comparison with a gear without lightening holes [3].
The research into the stresses of tooth-root, rim and web of thin-rimmed gear with offset web position, pointed out that not only the root stresses of such gear are much greater than for solid gear, but also there are much greater stresses at the joint of rim and web [4].
The aim of research presented in this paper has been to investigate the contribution of web thickness to maximum stress that appears at thin rim of spur gear with middle web position. The first step has been the development of geometrical and numerical model that would be able to properly simulate the load distribution along the facewidth, in order to consider the variations of rim and web thickness resulting by the corresponding deformation and stress of teeth foundation.
Based upon the obtained stress results and taking into account the fact that maximum equivalent rim stress appears at the joint of rim and web, the influence of rim and web thickness upon the rim

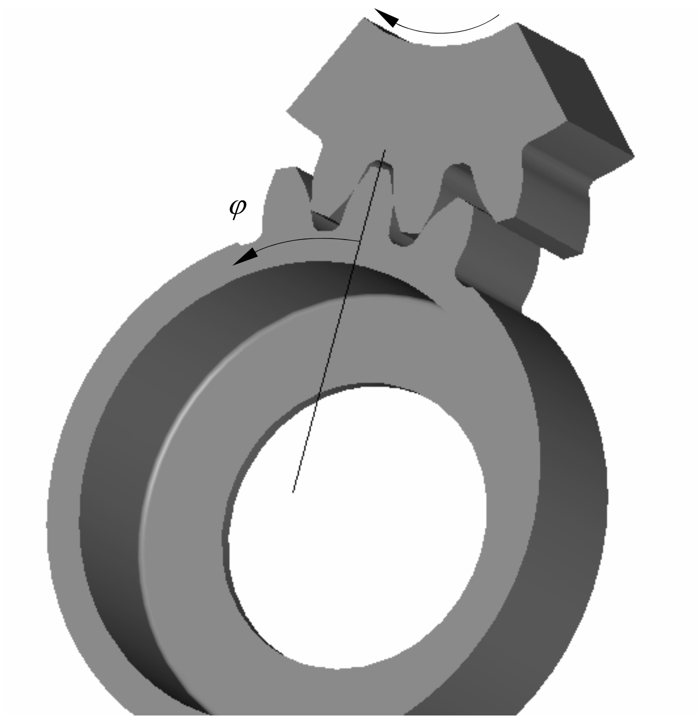


*Figure 1. One half of pinion-wheel model with the angle $\varphi$ determining the rim stress location in radial direction*

maximum stress magnitude and location, and the comparison of these influences, have been performed.

## 2. BASIC CONSIDERATIONS OF FEM STRESS CALCULATION

The 3D FEM model of spur solid pinion and thin-rimmed wheel is established at the outer point of single pair tooth contact. Numerical model is chosen after careful stress analysis of several different models and it satisfies in relation to both, the simulation of load distribution along the facewidth and simulation of gear body elements deformation modus. The FEM calculations are performed by means of software package I-DEAS [6].

The thin-rimmed wheel is modelled as whole ring with three teeth above it. The rim thickness is enlarged in accordance with [5] to take into account the effect of missing teeth on the rim rigidity.

The mating pinion and wheel have equal tooth geometrical parameters. During the calculation two wheel geometrical parameters are changed: the rim and web thickness. The rim thickness $s_R$ is adopted corresponding to thin rim taking values of $s_R/m$=3; 2; 1,5 and 1 ($m$ – module, mm), and the web thickness $s_w$ is adopted of $s_w/b$=0,1; 0,2; 0,3 and 0,4 ($b$ – facewidth value, mm). The fillet radius of rim and web joint, as well as the facewidth value, are kept constant during the calculations.

The imposed boundary conditions (modus of the loading, constraints, contact) and the meshing are in accordance with [7]. Due to the symmetry of geometry and load, the model with one half of adopted facewidth value is utilised.

In order to examine maximum equivalent von Mises rim stress, to determine its magnitude and location where it appears at inner rim surface, the rim stress range is established. The stress location in radial direction is expressed by the angle $\varphi$ measured from the centre line of the loaded tooth, towards its compressive side (Fig. 1). The rim stress is separated for the circle of rim and web joint where maximum equivalent rim stress is located in axial direction.

## 3. MAGNITUDE OF MAXIMUM RIM STRESS

In Fig. 2 the variation of maximum rim $\sigma_{Reqmax}$ stress is presented caused by the contribution of web thickness to thin rim stress. Maximum rim stress increases as the rim thickness decreases, and this becomes more obvious as the web thickness increases. For the thickest web ($s_w/b$=0,4) and the thinnest rim ($s_R/m$=1), the rim stress is 2,2 times the stress of the thickest rim ($s_R/m$=3) of equal web

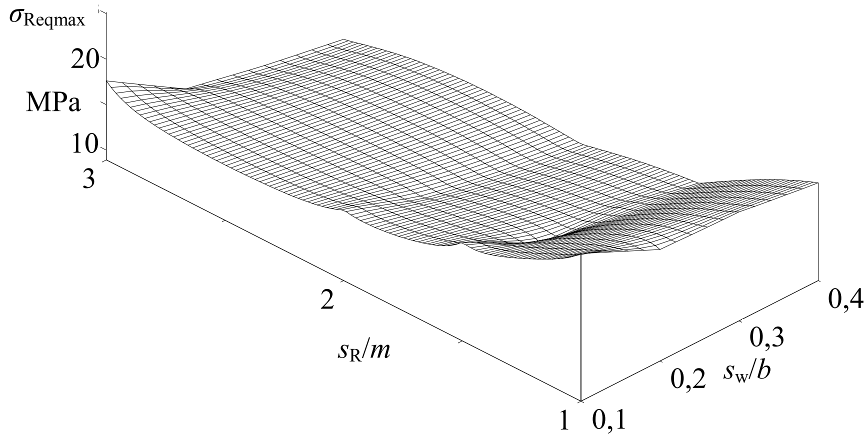


*Figure 2. Maximum equivalent rim stress related to the rim and web thickness*

thickness. In the same time, for the thinnest web ($s_w/b$=0,1), maximum rim stress of the thickest rim ($s_R/m$=3) deviates from the corresponding one of the thinnest rim ($s_R/m$=1) about 43%.

For certain rim thickness, the contribution of web thickness increment to maximum rim stress variation diminishes as the rim becomes thinner. The deviation of maximum rim stress for the thickest web $\sigma_{Reqmax0,4}$ ($s_w/b$=0,4) from the corresponding stress $\sigma_{Reqmax0,1}$ of the thinnest web ($s_w/b$=0,1) for certain rim thickness value is calculated and shown in Fig. 3. By the decreasing rim thickness, stress deviation diminishes from 97% of thicker rim ($s_R/m$=3), to 28% of the thinnest rim ($s_R/m$=1).

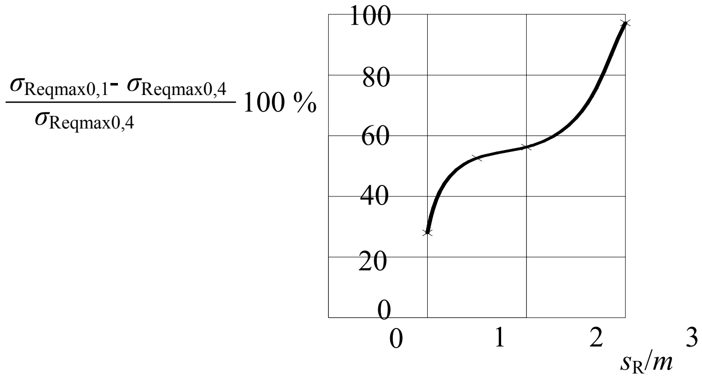


*Figure 3. The deviation of maximum rim stress for the thickest web $\sigma_{Reqmax0,4}$ from the corresponding stress $\sigma_{Reqmax0,1}$ of the thinnest web*

## 4. LOCATION OF MAXIMUM RIM STRESS

In the range of angle $\varphi$, equivalent stress at inner rim surface is presented for extreme values of the chosen rim and web thickness, i.e. for $s_R/m$=1; 3and $s_w/b$=0,1; 0,4. The stress distribution shape depends on the rim thickness and more obvious area of maximum equivalent stress appears for thinner rim, regardless of web thickness.

In order to examine the variation of rim location in radial direction where maximum stress occurs, the regression curves are determined that best fit the FEM stress results. These curves are the basis for the calculation of angle $\varphi$ corresponding to maximum rim stress. The results of angle $\varphi$ calculation are shown in Fig. 5 for the rim and web thickness under consideration.

As the rim thickness decreases, the location of maximum rim stress moves towards tension side of the loaded tooth i.e. maximum stress occurs for lower values of angle $\varphi$, regardless of web thickness value. This shift of maximum rim stress location depends on actual web thickness value, and it is the greatest for the thickest web ($s_w/b$=0,4), when the angle $\varphi$ for the thickest rim ($s_R/m$=3), is 2,5 times the angle corresponding to maximum stress location of the thinnest rim ($s_R/m$=1). For certain rim thickness, maximum rim stress location differs less than 3°, regardless of web thickness.

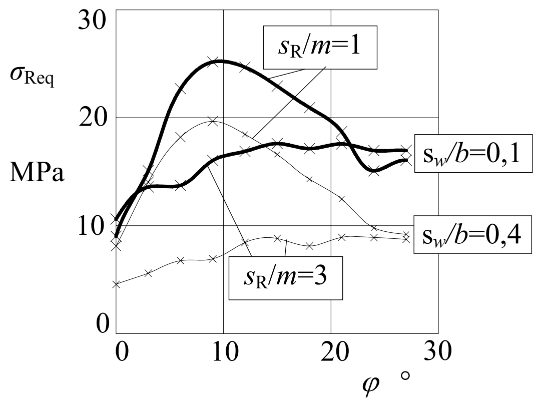


*Figure 4. The variation of equivalent stress at inner rim surface in radial direction for extreme values of rim and web thickness*

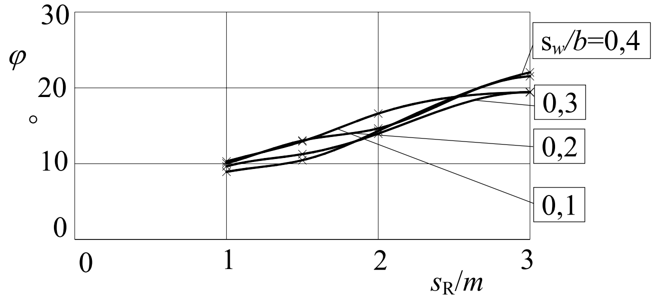


*Figure 5. The location of maximum equivalent rim stress in radial direction*

## 5. CONCLUSIONS

Maximum equivalent von Mises stress at inner rim surface of spur thin-rimmed gear with middle web position, is considerably effected by the variation of web thickness related to the stress magnitude corresponding to certain rim thickness.

The web thickness reduction contributes to the increment of maximum rim stress mostly in the case of greater value of thin rim thickness. As the rim thickness decreases the effect of web thickness upon maximum rim stress diminishes, and with the increment of web thickness the rim thickness becomes predominant factor of influence.

The location of maximum equivalent rim stress depends strongly on the rim thickness actual value. The reduction of rim thickness causes radial movement of maximum rim stress location towards the loaded tooth tension side that is more expressed for thicker webs.

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