12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

MAXIMUM WEB STRESS OF THIN-RIMMED GEAR

Gordana Marunić
University of Rijeka Faculty of Engineering
Vukovarska 58, 51000 Rijeka
Croatia

ABSTRACT

The paper presents a study on a web stress of spur thin-rimmed gear structure with symmetrically positioned web. Based on the suitable gear pair model and by means of the 3D FEM, maximum web stress is determined, stress values are compared, and stress variation in radial direction is analysed. Through the FEM calculations the rim and web thickness are varied in order to consider the contribution of actual gear structure to a gear deformation and consequently to the stress behavior of its parts.
Keywords: web stress, thin-rimmed gear, FEM

1. INTRODUCTION

The research into stress of involute spur gear with complex teeth foundation has been developed by following the development of adequate computational techniques and hardware facilities. A proper numerical approach adopted for a gear stress state determination has been exclusively 3D one.
Related to the actual gear structure depending on the size of rim and web, and the number of webs and their arrangement, the deformation of a body considerably effects the resulting teeth deformation and influences the load distribution along the tooth face width. Therefore, a consequential tooth loading simulation embraced by the boundary conditions appears to be essential when a stress state of such gears is under consideration.
The teeth design of spur gears is well established by standards and the attention is devoted constantly to improve the proposed procedures. For example, the standard ISO 6336-3 [1] has included the influence of a rim thickness for the calculation of tooth root bending strength.
It is obvious that the research into the stresses of rim and web has been not so often, unlike the investigation of tooth-root stress and the influence that parts of gear body have upon it.
A weight gains can be obtained by the adequate design of a gear body i.e. a rim and web, but the issues covering this area are not completely clarified, so they are still an interesting subjects of investigation.
In order to clarify the relationships between the root stresses and the gear structure, several studies were presented in [2, 3], dealing with the welded structure gears. Furthermore, a study by means of 3D FEM on web and rib stresses and tooth deflections of thin-rimmed spur gears with different web thickness and arrangements, are given in [4].
The deformations and stresses of spur gear with different web number and arrangement were analysed from numerical results obtained by appliance of the calculated load distribution along a tooth face width [5].
By use of finite element method and whole gear deformation model, and based on a loaded tooth contact analysis for actual tooth load distribution, the deformation and stresses at every part of thin-rimmed gear with offset web structure, were analysed [6].
The way to achieve weight gains by web with the lightening holes is presented in [7], and the actual fatigue cycle and the consequent safety margin for different load conditions were evaluated.

Table 1. Spur gear pairs data

Number of teeth	z_1=z_2	20	Rim thickness	s_R	30; 20; 15; 10 [mm]
Module	m	10 [mm]	Web thickness	b_s	40, 30, 20, 10 [mm]
Pressure angle	α	20 [°]	Material properties	Module of elasticity E	2,1 ·10^5 [N/mm^2]
Profile shift coefficient	x_1= x_2	0		Poisson\`s ratio ν	0,3
Facewidth	b	100 [mm]	Load per unit facewidth	F_{bn}/b	100 [N/mm]

In this paper a web stress calculation of thin-rimmed spur gear with middle web arrangement is based on the simulation of load distribution along a tooth face width resulting from actual gear deformation as a whole. The attention is devoted to the variation of the resulting web stress magnitude and distribution, effected by two parts of gear body, i.e. a web and rim thickness.

2. GEOMETRICAL AND NUMERICAL APPROACH

The adopted pinion-wheel model consists of pinion segment and whole wheel, having pinion and wheel equal geometrical parameters (Table 1). The supposed gear pairs engagement position is at the outer point of single pair tooth contact.

The calculation of stresses that correspond to the parts of wheel body i.e. the rim and web stresses, doesn't allow the approximation as in the case of tooth-root calculation. The deformation of complex wheel body is determined based on a whole wheel. The pinion segment corresponds to four teeth, with three teeth above rim, being the middle tooth the loaded one.

The chosen values of rim thickness cover the range proposed by ISO, and slightly overcome its upper and lower limit. Therefore the ratio of a rim thickness s_R and tooth height h_t, the so called backup ratio, takes values of s_R/h_t =0,44; 0,64; 0,92 and 1,34.

The web thickness b_S expressed by a tooth face width b covers the range of interest: b_S/b=0,1; 0,2; 0,3 and 0,4.

For a thin-rimmed gear structure with middle web arrangement, equivalent von Mises stress is determined by means of the 3D FEM calculation. The 3D numerical model is utilised according to the detailed model description in [8]. Equivalent stress is separated at the web surface by avoiding stress concentration regions.

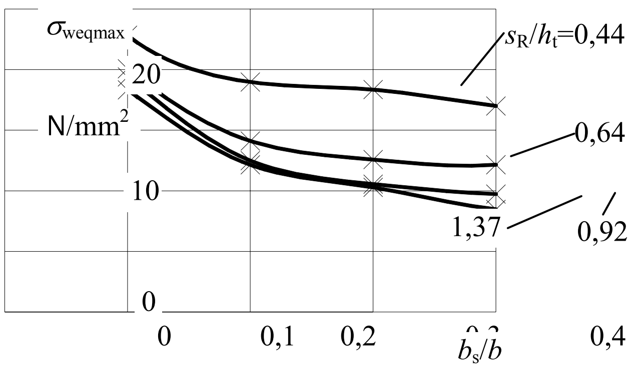

Figure 1. Maximum web stress regardless of its position in radial and angular direction related to a rim and web thickness.

3. MAXIMUM WEB STRESS

Maximum equivalent web stress σ_{weqmax}, its magnitude and location, strongly depends on a rim and web thickness. When maximum web stress is analysed regardless of its appearance in radial and angular direction, it can be concluded the following (see Fig. 1). Radial direction means a stress

observation going from a hub towards a rim, and angular direction refers to a stress-checking going from the loaded tooth centre line towards the tooth compressive side.
As the rim becomes thinner, the web thickness effect diminishes; the web stress is larger going from the thickest to thinnest web from more than two times (s_R/h_t=1,34), to about 34% (s_R/h_t=0,44), respectively.
The influence of rim thickness is mostly expressed in the case of the thickest web (b_S/b=0,4), where actual gear structure rigidity supported by thick web, causes the increment of web stress for about two times going from the highest (s_R/h_t=1,34) to the lowest (s_R/h_t=0,44) value of the rim thickness.
On Fig. 2 the distribution of web stress σ_{weq} for the location where maximum web stress is achieved for the chosen range of rim and web thickness, is presented in angular direction. This stress is found near the rim and it corresponds to s_R/h_t=0,44 and b_S/b=0,1. σ_{weq} reaches its peak value σ_{weqmax} under compressive side of the loaded tooth and it is slightly shifted from the tooth bottom centre.

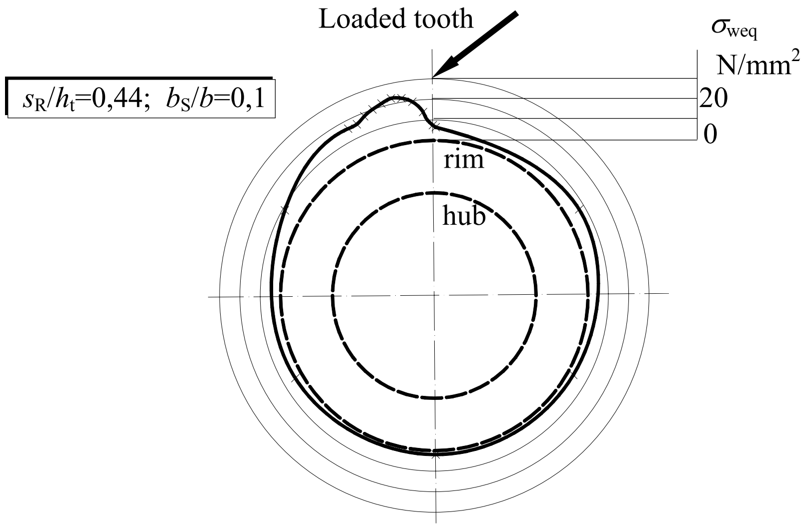

Figure 2. The distribution of web stress in angular direction for the location where maximum web stress appears.

4. VARIATION OF MAXIMUM WEB STRESS IN RADIAL DIRECTION

The variation of maximum web stress σ_{weqmax} determined in angular direction (the peak value for s_R/h_t=0,44; b_S/b=0,1 on Fig. 2), is followed in radial direction for each combination of a rim and web thickness (Fig. 3 a, b, c, d).
Going from the hub, the web stress σ_{weqmax} firstly decreases and then sharply increases approaching the rim where takes the values greater than near the hub, regardless of rim and web thickness. The described stress behavior differs only in the case of the thinnest web under consideration (b_S/b=0,1) for all rim thicknesses except for the thinnest rim (s_R/h_t=0,44).
The effect of web thickness on the web stress is more expressed for the location near the hub related to the location near the rim. The web stress for the thinnest web is from 2,7 to 3 times greater as the rim thickness decreases, than the stress for the thickest web. Near the rim, this effect diminishes going towards the thinnest rim, and the stress for the thinnest web is greater from 2 times to 34%, than the stress for the thickest one.
The variation of web stress in radial direction becomes more intensive as the rim thickness decreases and the web thickness increases; the web stress near the rim is about 2,8 times greater than the stress near the hub (s_R/h_t=0,44; b_S/b=0,4).

5. CONCLUSIONS

The reliable recommendations for a thin-rimmed gear teeth support design have to consider proper insight into a stress behavior of gear structure. The web is a part of gear body that can be subjected to obtain weight gains, and therefore its state of stress is worth to be clarified.
In relation to the combined contribution of rim and web thickness to the maximum equivalent web stress and its radial distribution, the obtained results allow several conclusions.

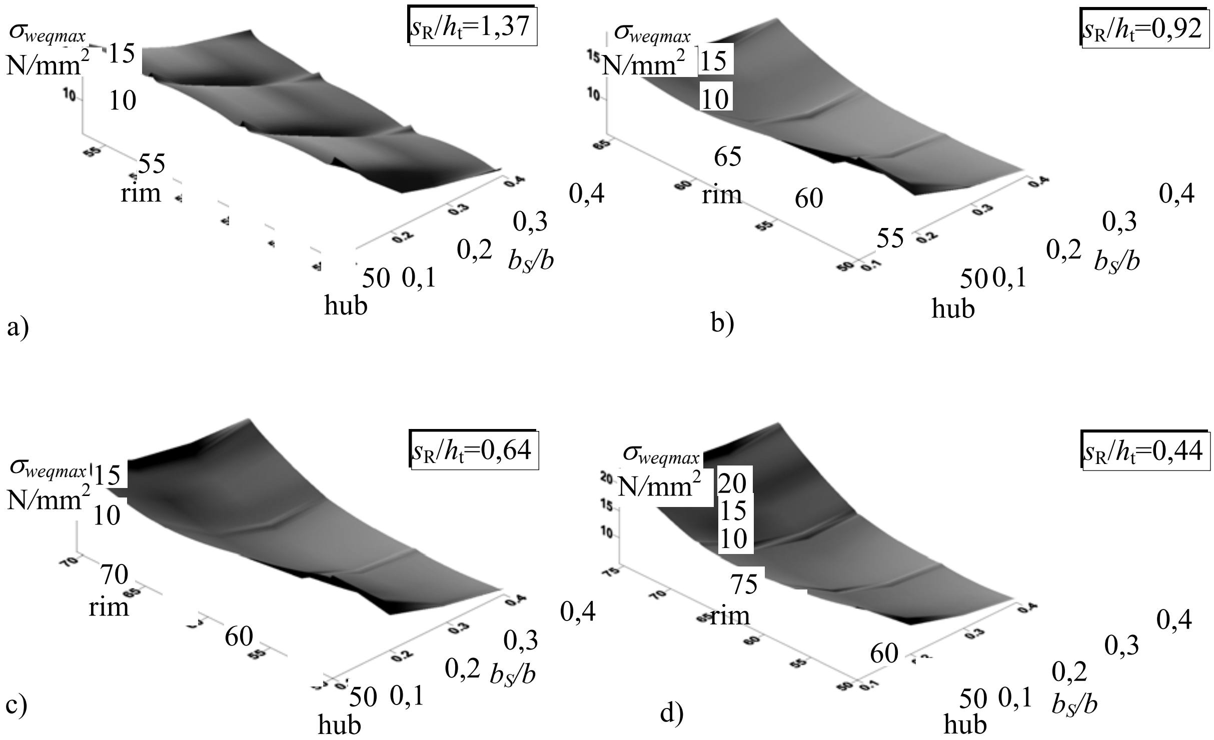

Figure 3. The variation of maximum web stress going from the hub towards the rim related to web thickness and for various rim thickness (a, b, c, d).

The influence of rim thickness decrease on the increment of maximum web stress is mostly expressed in the case of the thickest web. Maximum web stress decrement as the web thickness increases is mostly obvious for the thickest rim.

Maximum equivalent web stress for the chosen values of rim and web thickness is reached for the thinnest rim and web near the rim under compressive side of the loaded tooth and slightly shifted from the tooth bottom centre.

In radial direction, maximum web stress occurs near the hub for the thinnest web, except in the case of the thinnest rim. For all other web thicknesses under consideration, regardless of rim thickness, and for the combination of the thinnest web and rim, maximum web stress is located near the rim. The variation of maximum web stress becomes more intensive as the rim thickness decreases and the web thickness increases.

6. REFERENCES

[1] ISO 6336 - 3, Calculation of load capacity of spur and helical gears - Part 3: Calculation of tooth bending strength, 2006.,

[2] Oda S., Sayama T. & Shimatomi Y.: Study on Welded Structure Gears (1st Report, Effects of Rim Thickness on Root Stresses and Bending Fatigue Strength), Bulletin of the JSME, 1980.,

[3] Oda S., Sayama T. & Fukushima Y.: Study on Welded Structure Gears (2nd Report, Web Structures and Root Stress Distribution), Bulletin of the JSME, 1981.,

[4] Sayama T., Oda S. & Umezawa K.: Study on Welded Structure Gears (8th Report, Analyses of Web and Rib Stresses), Bulletin of the JSME, 1985.,

[5] Linke H., Mitschke W. & Senf M.: Einfluβ der Radkorpergestaltung auf die Tragfähigkeit von Stirnradverzahnungen, Maschinenbautechnik, 1983.,

[6] Li S. : Deformation and Bending Stress Analysis of Thin– Rimmed Gear, Journal of Mechanical Design, 2002.,

[7] Clerici P., Girotti A.& Perazzolo A.: Comparison of Web Stress Concentration Factors and Safety Margins for a Thin Webbed Spur Gear Subjected to Static and Cyclic Loading Conditions, International Power Transmission and Gearing Conference,1992.,

[8] Marunić G.: 3D FEM Complex Blank Gear Models, Proceedings of 5th International Scientific Conference RIM 2005, Bihać, Bosnia and Herzegovina, 2005.