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THE ANALYSIS OF THE MODULE OF CYLINDRICAL GEARS WITH THE GOAL OF OPTIMIZATION OF THE GEAR TRANSMITTERS

Dr.sc. Nijazi Ibrahimi, Dr.sc. Sadullah Avdiu, Msc. Riad Ramadani,
Faculty of Mechanical Engineering
University of Prishtina, Kosova

ABSTRACT
On the phase of dimensioning of the gear transmitters have influence several factors, wherefore especially is important the analyze of factors that has influence on their optimization. Wherefore, with the goal of realization of optimization of the transmitters, in this paper will be analyzed the module of the gears on the dependence of teeth number of the pinion and the material of the gears.
Key words: Module of the gears, Gear transmitters, Optimization, Critical strain.

1. INTRODUCTION

Gear power transmitters are part of mechanical group of high importance, which needs to fulfill required performance criteria as: center distance, dimensions, safety factor, efficiency factor, contact ratio, etc.
Choosing the *best model*, which needs to fulfill certain requirements of desired performance, imposes some limitation in the aspect of: assembling of gears pair, gears mesh, roughness of face and flank of gears, surface and volume durability, and other limitations.

2. ANALYSIS OF GEARS MODULE WITH THE GOAL OF OPTIMIZATION OF GEAR POWER TRANSMITTERS

Many factors influence on the dimensioning of gear power transmitters, therefore it is very important to make the analysis of factors that influence in their optimization.
Factors that influence on the optimization of gear transmitters are: gears module, gearing rate, center distance, material, safety factor, volume, etc.
In order to achieve optimization of each factor mentioned above, a gear pair was analyzed with following parameters:

- Pinion material: steel, type Ç.4732, for improvement,
- Gear material: steel, type Ç.1731 for improvement,
- Standard module: m_{n12}=4.5 mm,
- Number of teeth of pinion: z_1=19,
- Number of teeth of gear: z_2=80,
- Face width: b_{12}=100 mm,
- Helix angle: $\beta_{12}=14^o$,
- Center distance a_{12}=230 mm,
- Torque of pinion: T_1=387.324 N·mm,

3. DEPENDENCY OF MODULE ON THE NUMBER OF TEETH

Analysis of module in relation with number of teeth will be done based on the expression of safety factor on bending and pitting.
Expression of the module in relation of teeth number, based in the criteria of:

- Critical contact stress of teeth face:

$$m \geq \left[\frac{2 \cdot K_A K_V K_{H\alpha} K_{H\beta} \cdot T_1 (u+1) \cdot (Z_E Z_H Z_\varepsilon Z_\beta)^2 \cdot S_H^2}{\varphi_I \cdot [\sigma_H]_1^2 \cdot u \cdot z_1^3} \right]^{1/3} \tag{3.1}$$

- Based on the critical bending stress of teeth:

$$m \geq \left[\frac{2 \cdot K_A K_V K_{F\alpha} K_{F\beta} \cdot T_1 \cdot Y_{Fa} Y_{Sa} Y_\beta Y \cdot S_F^2}{\varphi_I \cdot [\sigma_F]_1 \cdot z_1^2} \right]^{1/3} \tag{3.2}$$

Calculated critical contact stress for the pinion is:

$$[\sigma_H]_1 = 723.203 \ N/mm^2$$

Permanent Dynamic durability of teeth face: σ_{Hlim}=600 N/mm^2,
Stress cycle life factor: Z_{NT}=1.15,
Lubricating factor: Z_L=1
Surface condition factor: Z_R=1.015,
Velocity factor: Z_v=0.9,
Hardness ratio factor for pitting resistance: Z_W=1.1,
Size factor: Z_x=1.0,
Tooth Shape factor: Z_H=2.43
Factor of materials elasticity: $Z_E == 189.812 \sqrt{N/mm^2}$
Contact ratio factor: Z_ε=0378,
Factor of helix: Z_β=0.985,
Factor of working conditions: K_A=1.25,
Dynamic factor: K_v=1.06,
Factor of load distribution: $K_{H\alpha}$=1.2,
Factor of load distribution along the sidelines:

$$K_{H\beta} = K_{F\beta}^{1.39} = 1.328^{1.39} = 1.483$$

$$K_{F\beta} \approx 1 + (K_\beta - 1) \cdot f_w \cdot f_p \cdot f_l = 1 + (1.16 - 1) \cdot 1.575 \cdot 1.0 \cdot 1.3 = 1.328$$

Critical bending stress calculated for teeth flank of pinion is:

$$[\sigma_F]_1 = 594.909 \ N/mm^2$$

Permanent Dynamic durability of teeth flank: σ_{Flim}=285 N/mm^2,
Stress cycle life factor: Y_{NT}=1.0,
Stress concentration factor on teeth: Y_{ST}=2.0,
Relative factor of materials sensitivity on stress concentration: $Y_{\delta relT}$=0.98,
Relative roughness factor: Y_{RrelT}=1.065,
Factor of the size of the cut: Y_x=1.0,
Factor of teeth form: Y_{Fa}=2.87,
Stress concentration factor on teeth flank: Y_{sa}=1.61,
Contact ratio factor: Y_ε=0.68,
Factor of helix angle of sidelines: Y_β=0.88,
Load distribution factor on teeth pair: $K_{F\alpha}$=1.2,
In fig. 3.1 is represented geometrical interpretation of expressions (3.1) and (3.2) for: steel, Ç.4732, for improvement.

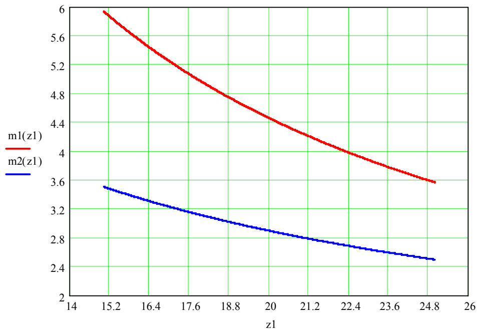

Fig.3.1. Dependency of module on number of teeth z_1, for steel for improvement based on the critical stress of: $m_1(z_1)$ – pitting, $m_2(z_1)$ – bending.

From the Fig.3.1 we can conclude that, with the increase of number of teeth this is a decrease of gears module, for the steel material for improvement. Module that is calculated based on the critical contact stress of teeth face has higher values than the one calculated based on the critical bending stress of teeth flank, because gears material is steel for improvement. Therefore as a conclusion, criteria for selection of gears module is the one that is determined based on the critical contact stress of teeth.
Because the determination of gears module is influenced by type of material, further, the module will be determined based on the expressions (3.1) and (3.2) for material, steel for case-harden.
Calculated contact stress for teeth for pinion is:

$$[\sigma_H]_1 = 1659.863\ N/mm^2$$

Other parameters that vary based on the chosen material are:
Permanent Dynamic durability of teeth face: σ_{Hlim}=1470N/mm^2,
Surface condition factor: Z_R=1.03,
Velocity factor: Z_v=0.954,
Hardness ratio factor for pitting resistance: Z_W=1,
Also, for the material steel for case-harden, critical bending stress calculated for teeth flank, for pinion is:

$$[\sigma_F]_1 = 906.741\,N/mm^2$$

Other parameters that vary based on the chosen material are:
Permanent Dynamic durability of teeth flank: σ_{Flim}=285 N/mm^2,
Relative factor of materials sensitivity on stress concentration: $Y_{\delta relT}$=0.99,
Load distribution factor on teeth pair: $K_{F\alpha}$=1.2,
In fig.3.2 is represented geometrical interpretation of expressions (3.1) and (3.2) for: steel, Ç.4320, for case-harden.

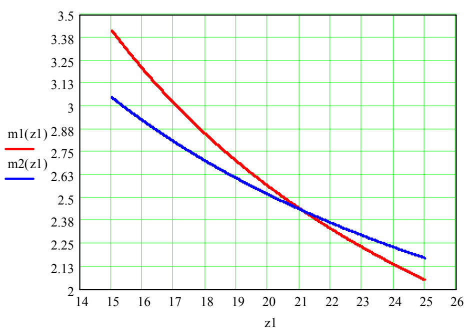

Fig.3.2. Dependency of module on the number of teeth z_1, for steel for case-harden, based on the critical stress of: $m_1(z_1)$ – $m_1(z_1)$ – pitting, $m_2(z_1)$ – bending.

From the Fig.3.2 we can conclude that, with the increase of number of teeth this is a decrease of gears module, for the steel materiel for case-harden. Module that is calculated based on the critical contact stress of teeth has higher values than the one calculated based on the critical bending stress of teeth flank up to the teeth number z_1 = 21. For the number of teeth of the pinion z_1 > 21 is the opposite, because the gears material is steel for case-harden. As a conclusion, this boundary value can be taken as a criterion for choosing gear module.

4. CONCLUSION

Based on the analysis of gears module depending on teeth number of the pinion and gears material it can conclude that:

- with the increase of number of teeth, gears module decreases, for the steel material for improvement, so criteria for selection of gears module is the one that is determined based on the critical contact stress of gear teeth .
- with the increase of number of teeth, gears module decreases, for the steel materiel for case-harden. Module that is calculated based on the critical contact stress of teeth has higher values than the one calculated based on the critical bending stress of teeth flank up to the teeth number z_1 = 21. For the number of teeth z_1 > 21 is the opposite, because the gears material is steel for case-harden.

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