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Investigating the Stress in the Body of the Flexible Wheel of a Radial Harmonic Transmission

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The paper presents a study of the strains and stress state in the flexible toothed wheel of a radial harmonic transmission, in the case of its deformation by a 2 roller mechanical wave generator. Dynamic research has pursued the numerical simulation of a flexible toothed wheel, in the form of a long circular tube, open at one end, by using the finite element method and using the SolidWorks Simulation program in elastic range.

***Keywords**: radial harmonic transmission, flexible wheel, numerical simulation, deformation, stress*

1. Introduction

Harmonic transmission are used in almost all of the cutting edge areas of modern technology, due to the many advantages it presents: high kinematic precision, high transmission ratio, high mechanical efficiency, compact and modular construction, gauge and reduced mass etc [1, 2, 3, 4, 5, 6, 7, 11, 17].

In the category of these modern transmissions is included the radial harmonic transmission, which features a completely different operating principle than classic gears.

At the radial harmonic transmission, the rotation motion is transmitted by means of elastic deformations, which propagates after a harmonious law on the periphery of one of its elements called flexible toothed wheel [4, 5, 7, 8, 9, 13].

The radial harmonic transmission (Figure 1) is based on the following three elements: the wave generator (1) - produces elliptical deformation of the flexible toothed wheel, which will gear with the rigid toothed wheel; the flexible toothed wheel (2) - it has the form of a thin walled cylindrical tube with external teeth; the rigid toothed wheel (3) - is the fixed element and has internal teeth.

In section A-A of the radial harmonic transmission, we observe that in the areas that are in the direction of the major axis of the ellipse (a – a) - the teeth of the two wheels will be completely enter into engagement, and in areas in the direction of the small axis of the ellipse (b – b) - the teeth of the two wheels will be completely out of engagement.

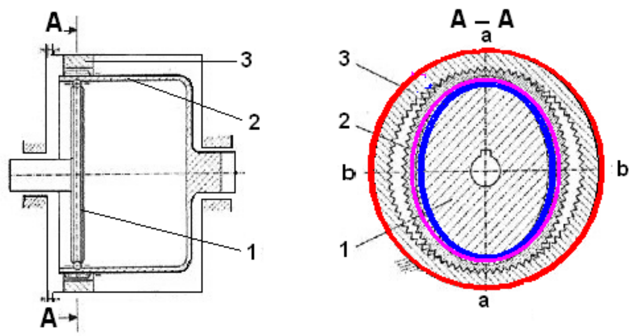


Figure 1. The radial harmonic transmission

The functional performance and durability of radial harmonic drive are greatly influenced by the durability of flexible toothed wheel, which is the most stressed element in the drive [10, 12, 13]. This aspect has imposed the need for research of the stress and strains state of the flexible toothed wheel, in assessing the dynamic behavior of flexible wheel.

This paper presents a detailed analysis of the stress and strains state on the wall of the flexible toothed wheel of a radial harmonic transmission.

2. Numerical simulation of the flexible toothed wheel

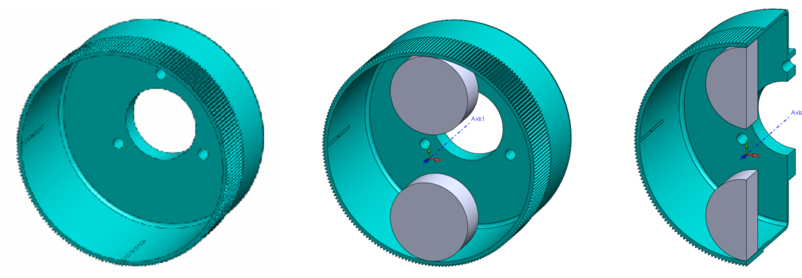
In order to investigate the stress and strains state, the numerical simulation of the flexible toothed wheel was performed, using the finite element method and the SolidWorks Simulation module.

The stages were as follows [14, 15, 16]:

- 3D geometry modeling the flexible toothed wheel and wave generator where the 2 rollers in SolidWorks CAD software;
- defining case analysis;
- defining material from the library of materials;
- definition restrictions and applying the loading;
- finite element mesh of the model tested;
- calculating the strains and the stress by SolidWorks Simulation module;
- view and analyze the results.

In numerical simulation, the flexible wheel of the radial harmonic transmission was modeled by a long cylindrical tube open at one end (Figure 2, a), defined by: radius, r = 29,3 mm, length, l = 60 mm and the constant wall thickness, s = 0.6 mm, which is provided with an external toothing with a width of b = 15 mm.

The analysis model (Figure 2, b) is composed of a flexible toothed wheel of radial harmonic transmission and a wave generator with 2 rollers. The two rolls modeled by 2 identical circular cylinders, characterized by cylinder diameter, d_r = 22 mm and height of the cylinder, b_r = 8 mm.



a. b.

Figure 2. The analysis model

SolidWorks Simulation operates with the concept of "Study", specifying the specific characteristics of the analysis: analysis type and associated options, materials, set load and boundary conditions and meshing of the analyzed model.

To wave generator where the 2 rollers, the contact between the flexible toothed wheel and the generator is produced on the inner side of the wheel in the areas N and S (Figure 3).

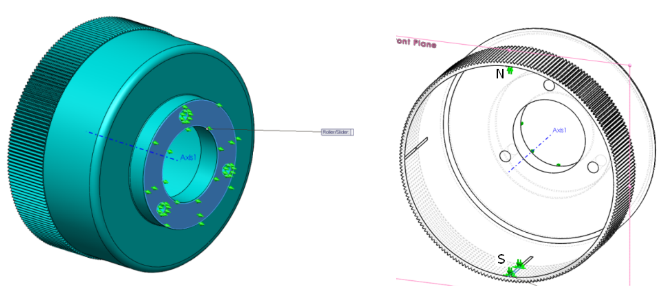


Figure 3. The restrictions applied

In these contact areas, the following restrictions will apply to the flexible toothed wheel: two restrictions of value 0 that cancels displacement of the contact areas (N respectively S) in the Ox direction and two restrictions of 0.3 mm applied to the outside wheel, which materializes the deformation in the Oy direction of the flexible wheel to the 2 rollers of the wave generator.

After completing the specified steps, it was performed numerical simulation processing of the dynamic behaviour of the flexible toothed wheel, in order to determine and display graphically of the deformations and tension state.

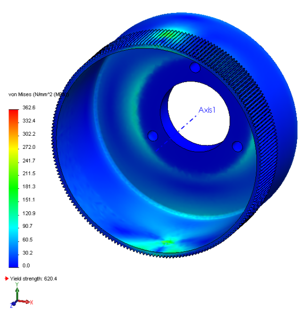
The results of the numerical simulation of the flexible toothed wheel can be viewed and consulted graphically (charts and colour maps) or analytically (numerical values for von Mises stress).

3. Numerical simulation results

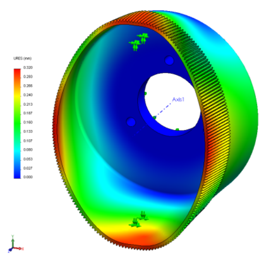
In the numerical analysis we studied the strains and stress variations from the body of the flexible toothed wheel, depending on the charging of the radial harmonic transmission.

Thus, by successive runs of the numerical analysis program were recorded maximum values of displacements and von Mises stress for all 6 steps of the charging, M_{t2} = (0, 100, 200, 300, 400, 500) N·m.

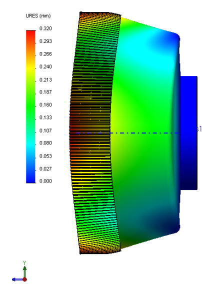
Figure 4 shows, in the form of color maps, that the von Mises stress distribution and the resultant displacement (Δ), if the deformation of the flexible wheel to the wave generator where the 2 rolls.



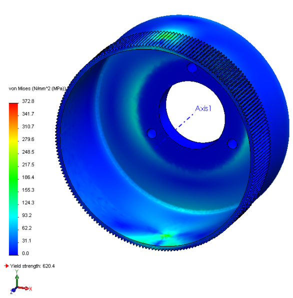
$\sigma_{von\ Mises}$- M_{t2} = 0 Nm



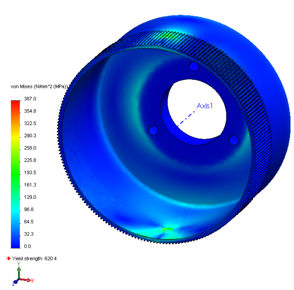
Δ - M_{t2} = 0 Nm



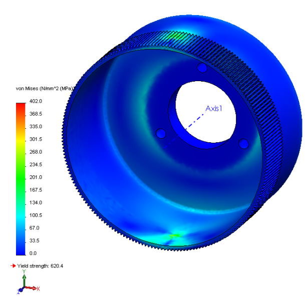
Δ - M_{t2} = 0 Nm



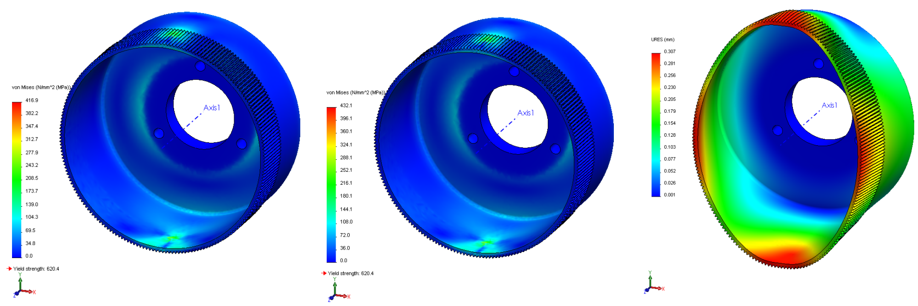
$\sigma_{von\ Mises}$- M_{t2} = 100 Nm



$\sigma_{von\ Mises}$- M_{t2} = 200 Nm



$\sigma_{von\ Mises}$ - M_{t2} = 300 Nm



$\sigma_{von\ Mises}$- M_{t2} = 400 Nm $\sigma_{von\ Mises}$- M_{t2} = 500 Nm Δ - M_{t2} = 500 Nm

Figure 4. The maximum von Mises stress

4. Conclusion

The paper presents the results of numerical simulation of the flexible toothed wheel of the radial harmonic transmission, with the wave generator where 2 rollers, allowing to evaluate the dynamic behavior of the flexible wheel.

From the analysis of these results we can see that the stress that arise in the wall of the flexible toothed wheel are dependent on the transmission load, presenting a slightly increasing character (σ_{vMmax} ϵ [362,6; 432,8] MPa) with increasing torque (M_{t2} ϵ [0; 500] N·m).

It is also noted that at low transmission loads ($M_{t2} \leq 100$ Nm) the variation in the maximum stress (σ_{vMmax}) is insignificant.

The maximum value of the stress (σ_{vM}) occurs in the immediate vicinity of the point of application of the elastic deformation force of the flexible toothed wheel from the roller of the wave generator, and this stress is well below the yield strength of the material of the wheel ($\sigma_{vM} < \sigma_c = 620{,}422$ MPa).

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