STRESS AND STRAIN STATE OF CYCLOID GEAR UNDER DYNAMIC LOADS

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Abstract *Besides the large transmission ratio, extremely compact design and high efficiency ratio, cycloid drives are recognizable according to very good working characteristics in dynamic load conditions. Thanks to the simultaneous coupling of almost one third of the number of cycloid gear teeth, cycloid drives can accept large short-term shock loads without any consequences.*

The most important element of cycloid drive in terms of geometric and kinematic complexity (cycloid gear tooth profile represents equidistant of shortened epitrochoid) as well in relation to the nature of the load on which is exposed, certainly the cycloid gear. This paper analyses the stress-strain state of cycloid gear under real working conditions (in terms of dynamic loads). Observed the different load cases and finite element is determined distribution of strains and stresses on the body cycloid gear.

Key words: *cycloid drive, cycloid gear, dynamic load, FE analysis*

1. INTRODUCTION

Cycloid drives from day to day due to excellent performance characteristics that they have (large transmission ratio, a very compact design, light weight, high efficiency ratio, exceptional reliability ...) are increasingly present in today's global market, Figure 1. The first mathematical model for calculation of basic geometric and kinematic parameters cycloid drives, and loads that occur on its main elements define the *Kudrijavcev*, [1]. A very detailed analysis of the distribution of load and calculation of efficiency ratio of cycloid drives is presented in the papers [2,3,4]. *Sensinger* conducted an optimization of basic parameters cycloid drives (cycloid gear tooth profile, efficiency ratio, stress state), [5].

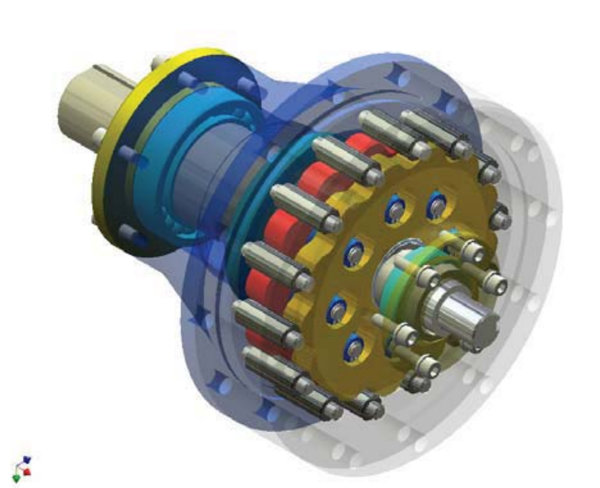

Fig.1. Model of single stage cycloid reducer

The large amount of modern researching's is aimed at developing new concepts of cycloid drives in order to obtain a more favourable performance of this group of power transmission, [6,7,8]. Detailed analysis of the stress-strain state of cycloid gear in static conditions (numerical and experimental) is presented in this paper [9]. However, in real working conditions the dominant are dynamic loads. *Kahraman* has defined a series of dynamic models of planetary gears that quite accurately describe their dynamic behaviour in real working conditions, [10]. When it comes to the dynamic behaviour cycloid drives, researching in this field are in a quite smaller amount related to classical planetary reducers. A result of that researching's presented in the papers [11,12,13].

In this paper the analyses of stress-strain state of cycloid gear are presented, under the influence of dynamic loads on a specific single stage cycloid reducer, Figure 1.

2. NUMERICAL ANALYSIS OF SRESS-STRAIN STATE OF CYCLOID GEAR UNDER DYNAMIC LOADS

Li Lixing defined expressions for the calculation of s and backlash of cycloid gear teeth and rollers of stationary central gear, [14]. Based on these expressions, in the paper [15], a mathematical model is developed that defines the dynamic behaviour of single-stage cycloid drive, Figure 2. The main output parameter of the mathematical model is a normal dynamic force F_{din} which occurs in contact cycloid gear tooth and roller of stationary central gear.

In this paper the single-stage cycloid reducer, with the following working characteristics, has been analysed:

- Input power: P_{in} = 5,5 kW;
- Input number of revolutions: n_{in} = 1500 min^{-1};
- Gear ratio: u = 11;
- Number of cycloid gear teeth: z = 11;
- Eccentricity: e = 4 mm.

A series of different numerical models of cycloid gear are made. Modelling, pre-processing and post processing were done in the software package FEMAP, while the calculation itself done in the program MSC NASTRAN.

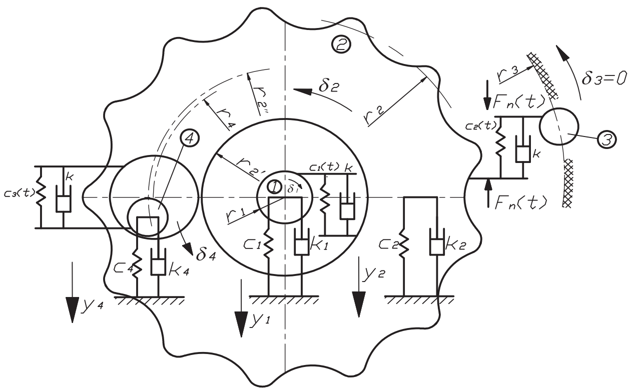

Fig.2. Dynamic model of single-stage cycloid reducer

That the analysis could be realized, a whole series of realistic and reasonable assumptions are made, as follows:

- Cycloid gear is elastic, deformable body,
- Single, double and triple contacts are analysed,
- In all the numerical models, in contact, there are two output rollers with the body cycloid gear and these places are used for fix constraints,
- Supports are placed at locations where rollers needle beds (the eccentric) in contact with cycloid gear (a total of nine rollers),
- External load is the dynamic force F_{din},
- Problem is treated as a planar problem,
- For all models of dynamic excitation force is distributed in three nodes that are located on its force acting line,
- Diagrams of stress and strain are given for the corresponding finite elements, not nodes.

Only the models with most representative results are presented.

Model 1: *Single contact*

- *Number of finite elements:* 9227,
- *Number of nodes:* 9753,
- *Nodes of dynamic loading F_{din}*: 356 (element 5227), 5737, 5739,
- *Nodes of output roller 2:* 955 (element 6392), 956, 957,
- *Nodes of output roller 3:* 1044 (element 8043).

Model 2: *Double contact*

- *Number of finite elements:* 9227,
- *Number of nodes:* 9753,
- *Nodes of dynamic loading F_{din}*: 356 (element 5227), 5737, 5739,
- *Nodes of output roller 2:* 955 (element 6392), 956, 957,
- *Nodes of output roller 3:* 1044 (element 8043),
- *Nodes of normal force loading F_{N2}:* 318 (element 4527), 5466, 5469.

Model 3: *Triple contact*

- *Number of finite elements:* 9227,
- *Number of nodes:* 9753,
- *Nodes of dynamic loading F_{din}*: 356 (element 5227), 5737 (element 5276), 5739 (element 5277),
- *Nodes of output roller 2:* 955 (element 6392), 956 (element 6370), 957,
- *Nodes of output roller 3:* 1044 (element 8043),
- *Nodes of normal force loading F_{N2}:* 318 (element 4527), 5466, 5469,
- *Nodes of normal force loading F_{N1}:* 284 (element 4297), 5114, 5117.

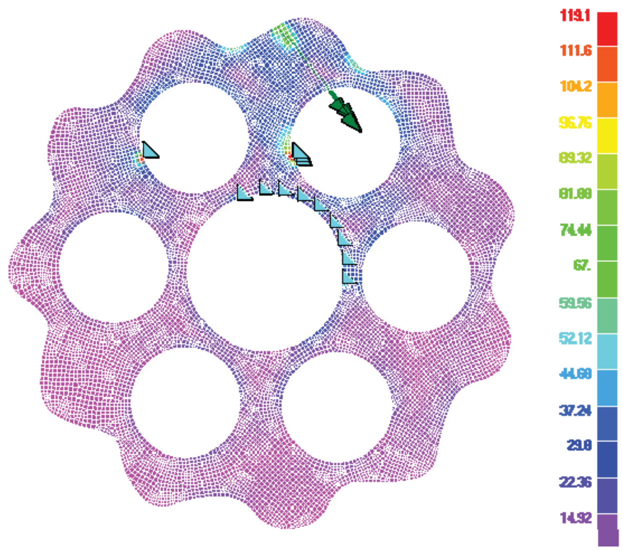

Fig.3. Von-Misses stress distribution on cycloid gear – model 1

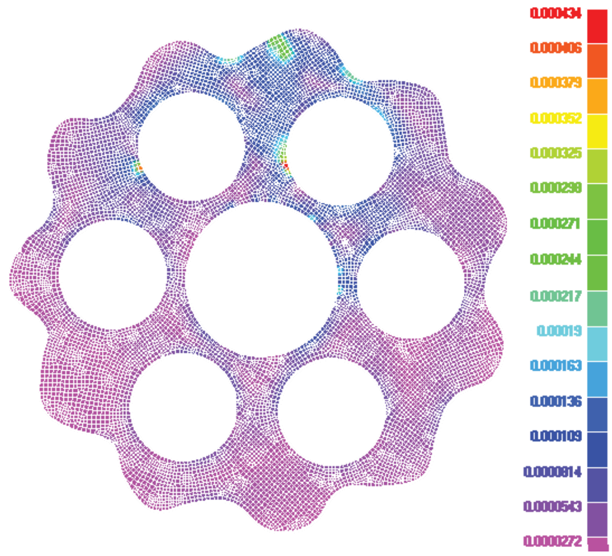

Fig.4. Strain distribution on cycloid gear – model 1

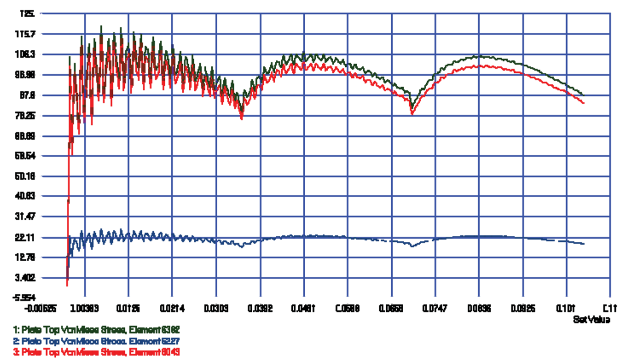

Fig.5. Von-Misses stress distribution on cycloid gear (model 1) for finite elements 6392, 5227 and 8043

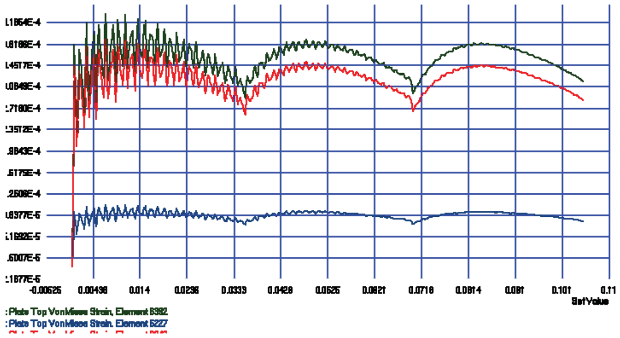

Fig.6. Strain distribution on cycloid gear (model 1) for finite elements 6392, 5227 and 8043

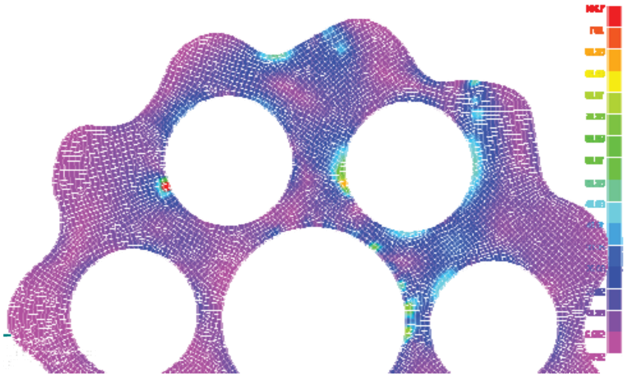

Fig.7. Von-Misses stress distribution on cycloid gear – model 2

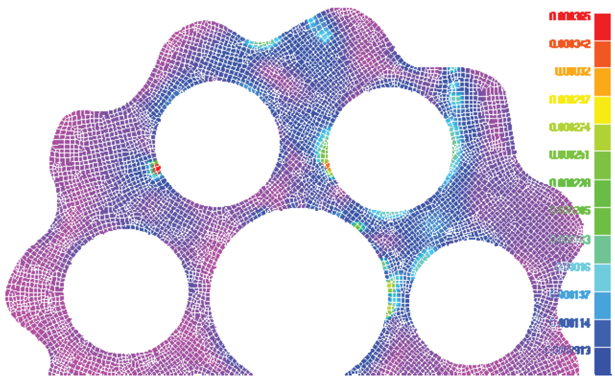

Fig.8. Strain distribution on cycloid gear – model 2

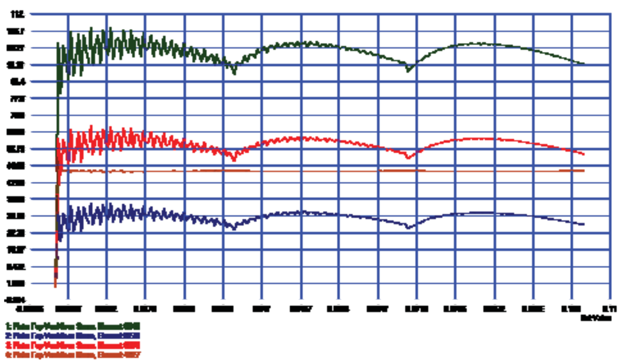

Fig.9. Von-Misses stress distribution on cycloid gear (model 2) for finite elements 8043, 5276, 6370, 4527

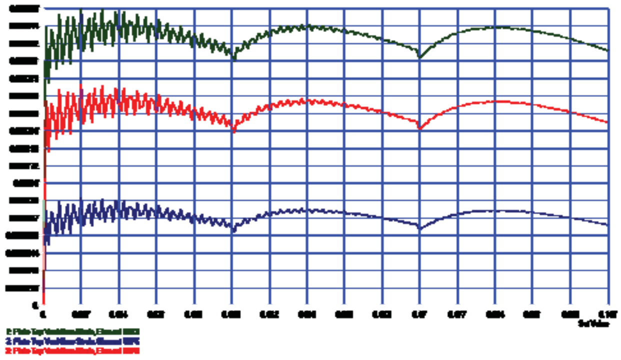

Fig.10. Strain distribution on cycloid gear (model 2) for finite elements 8043,5276, 6370

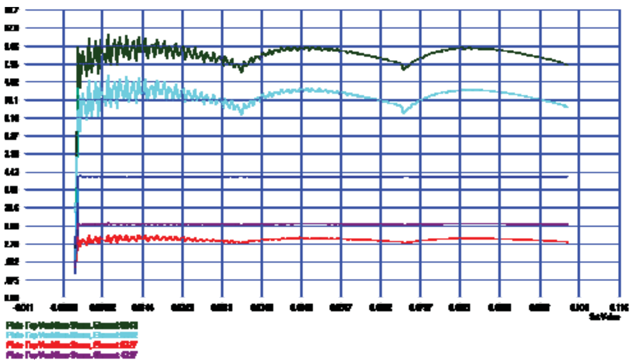

Fig.11. Von-Misses stress distribution on cycloid gear (model 3) for finite elements 8043, 6392, 5227, 4297 and 4527

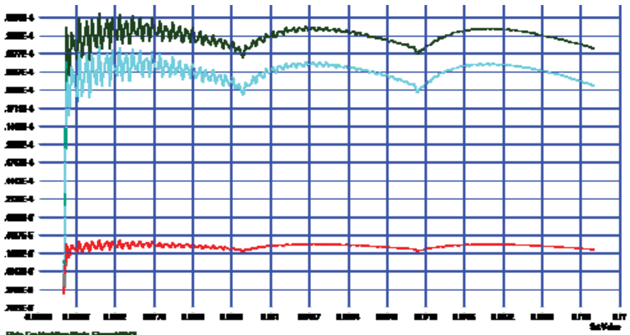

Fig.12. Strain distribution on cycloid gear (model 3) for finite elements 8043, 6392 and 5227

The maximum values Von-Misses stress and strain for all three analysed models are given in Table 1.

Table 1.Maximum values of Von-Misses stress and strains

Model	Max. *Von-Misses* stress, MPa	Max. strain, mm
1	119,1	0,000434
2	106,7	0,000365
3	104,7	0,000358

Shown in Table 1, the maximum value of the Von-Misses stress and strain is when the cycloid gear has the single contact with output rollers, on the place of output roller 2 supports.

3. CONCLUSION

In the framework of this paper the analysis of stress-strain state is single-stage cycloid drive, in terms of dynamic loading using FE analysis, was carried out. A whole series of numerical models have made and a large number of simulations were done. Based on the obtained results the following conclusions can be made:

- The shape of the diagram distribution Von-Misses stress and strain selected nodes and finite elements is almost identical to the form of the corresponding excitation dynamic forces, especially in the zone of the same, [15],
- The maximum value of the stress and strain vary from the corresponding maximum values of stress and strain in case the fact of constant excitation force,
- Moving away from the working zone of dynamic excitation force, stress and strain amplitude is significantly reduced,
- The most critical case is the case of a single contact, which cycloid drives almost never is present,
- The values obtained stress and strain are within the allowed limits, which provide normal and reliable operation within a specified work life of power transmitter.
- The next step, which would confirm the above defined conclusions, would be the experimental analysis of the stress-strain state of cycloid gear in conditions of dynamic loads.

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