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A FINITE ELEMENT ANALYSIS METHOD APPLIED TO THE CICLOYD GEAR REDUCTION'S SATELLITE GEAR

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Abstract: *The paper shows the particularities of the static behaviour of the planetary gear of the cycloid reduction gear with roller teeth depending on the number of the roller teeth respective on the number of homokinetic coupling's thumb in direct contact with the satellite gear. We propose a model of analysis with Finite Element Method of the contact situation of the satellite gear with the gearing roller teeth and the gearing thumbs. Also, we analyse the reactions values in the contact points, resulted in different hypothesis.*
Key words: *static analysis, cycloid reduction gear, reactions, direct contact points.*

1. INTRODUCTION

In the cycloid reduction gear design process, to determine the optimal dimensions of the satellite gear's geometrical elements we need to observe the stress and deformations while it is being loaded. One of the various computational methods for calculating deformation and stress conditions is the Finite Element Analysis (FEA).

In the very complex situation of the satellite gear gearing with some of the sun gear's roller teeth simultaneously with some of the homokinetic coupling's thumb, we can obtain the reactions values in the contact points in different gearing hypothesis through analytical calculation, also these can be measured or can be determinated using FEA method.

2. REACTIONS IN THE CONTACT POINTS OF THE SATELLITE GEAR

We know that the satellite gear of the cycloid reduction gear with roller teeth is strained by following reactions:

- R_{12} **reaction** resulted on the interaction of the satellite gear 2 with the port-satellite-bar 1, it passes through the center of the hole and we know it size and direction.

- R_{32i} **reaction** resulted on the interaction of the cycloid profile of the satellite gear 2 with the roller teeth of the sun gear 3, it has the point of application in tangency point of the roller tooth at the cycloid profile and it is orientated in relation with the common normal which passes through the gearing pole, without knowing his size;

- R_{42j} **reaction** resulted on the interaction of the hole of the satellite gear 2 with the thumb of the transversely coupling 4. It has the point of application in the point of tangency of the thumb with the hole and it has the direction parallel with the centers' line, without knowing his size.

The satellite gear is strained also by the centrifugal force Fc, created due to the planetary assembling of the satellite gear, it has the application point in the center of the satellite gear and the direction is the centers' line.

We suppose that we know the drive moment of the drive shaft being the same with the electromotor shaft moment.

We determine the reaction R_{12} resulted of the interaction of the eccentric with the satellite gear from the equilibrium equations of the satellite gear, with the formula:

$$R_{12} = M_m \ / \ 2a \tag{1}$$

where: - M_m is the drive moment,

- a is the centroides eccentricity,

and its direction is perpendicular on the centres' line.

Also, we can evaluate the centrifugal force Fc who acts on the centroides centers' line having the following expression:

$$F_c = m\omega^2 a \, , \tag{2}$$

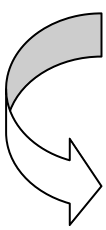
where: - m is the satellite gear mass,

- ω is the drive shaft angular speed,
- a is the length of the port-satellite-bar.

Through the finite element method we determine the reactions, the displacements and the stress following the bellow presented steps:

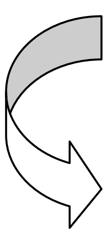
START structural linear static Analysis

PREPROCESSING



- o Build Geometry Save the geometry
- o Define Materials:
  - ▪ Set preferences
  - ▪ Define Material properties
  - ▪ Define element type and options
  - ▪ Define real constants
- o Generate Mesh:
  - ▪ Mesh the area
  - ▪ Save the database

SOLUTION PHASE



- o Apply loads
  - ▪ Apply displacement constraints
  - ▪ Apply pressure loads
- o Solve

POSTPROCESSING PHASE

- o Read Results
- o Plot de deformation shape
- o Plot the von Mises equivalent stress
- o List reaction solution

QUIT the analysis Program

3. THE FEA METHOD ANALIYSIS APLIED TO THE SATELLITE GEAR

We have obtained the cycloid profile of the satellite gear with a generating program written in AutoLISP ruled on the AutoCAD utilitarian program. We have built the 2D geometry of the satellite gear in AutoCAD and, at the end, we have transferred the satellite gear 2D model in Mechanical Desktop6 and we run through the finite element method's steps.

For the present analyse we take into consideration a cycloid gear reduction with roller teeth with the following dimensions and parameters:

- the number of sun gear's roller teeth, $z_2=18$,
- the transmission ratio, $i=z_2-1$, $i=17$,
- the radius of the roller teeth, $r_B=5$ mm,
- the roller teeth's disposal circle radius $r_2=eaz_2$, $r_2=70.398$ mm
- the radius of the generating centroide, $r_g=az_2$, $r_g=3.911$ mm
- the radius of the base centroide, $r_b=a(z_2-1)$, $r_b=66.487$ mm
- the distance between the centroides' centers, $a=2.4$ mm,
- the eccentricity of the generating point position, $e=0.614$ mm,
- the number of homokinetic coupling's thumbs, $n_d=10$,
- the radius of the thumbs, $r_d=7.6$ mm,
- the diameter of the satellite gear's holes, $d_g=20$ mm,
- the thumbs' disposal circle radius, $r_w=45$ mm,
- the thickness of the satellite gear, $b=12$ mm.

In this particular case, the reaction is R_{12}=1539.37[N], and the calculate centrifugal force is F_c=39.77[N] for a drive shaft angular speed ω=151.844 rad/sec.

We assume plane stress for this analysis, since the satellite gear is thin in the z direction (12 mm) compared to its x and y dimensions and since the pressure loads act only in the x-y plane. The study of the reactions' variations is approached in the case of distribution of the reactions on the satellite gear in the contact points of all gearing roller teeth and all gearing thumbs, Fig.1.

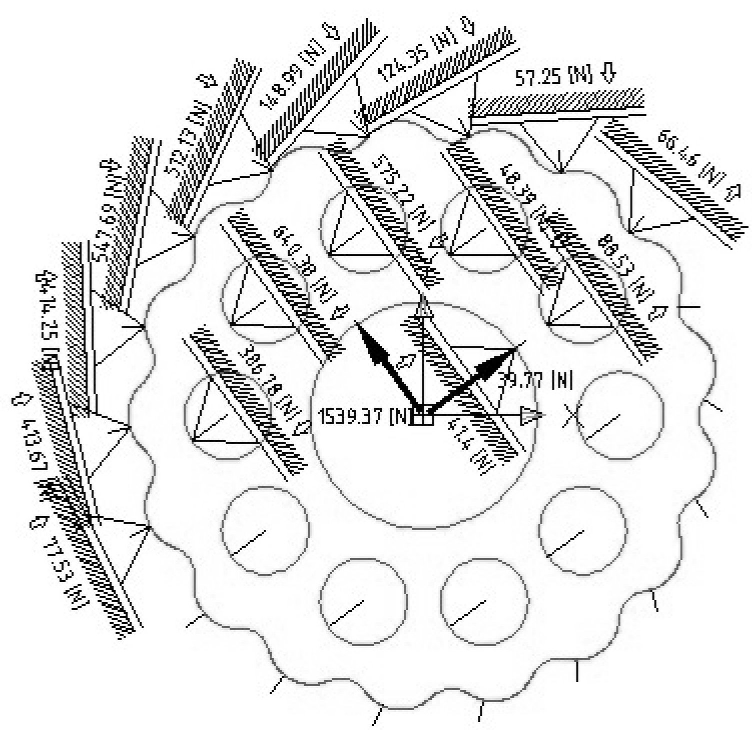


Fig. 1 *The reactions in the contact points of the gearing roller teeth and the gearing thumbs*

To this contact situation we have built a first diagram for the reactions given by the gearing roller teeth and a second diagram for the reactions given by the gearing thumbs, Fig.2.

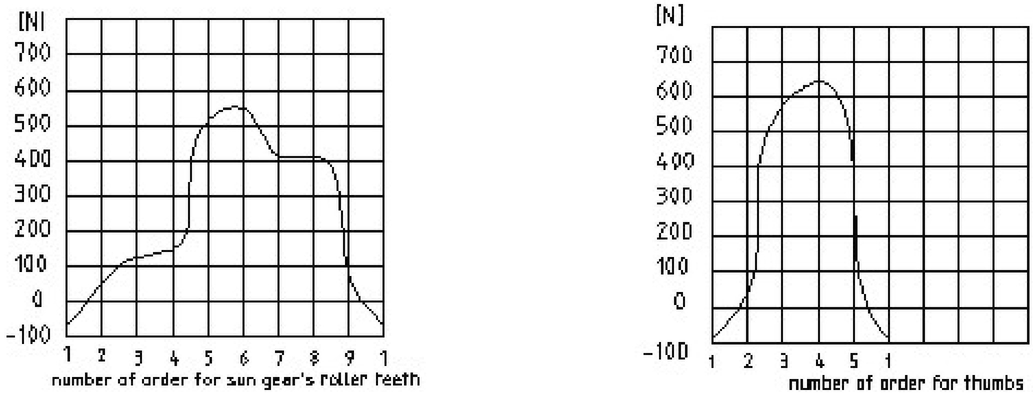


Fig. 2 *The diagrams for the reactions in the contact points of gearing roller teeth and in the contact points of the gearing thumbs*

Further on, we analyse the displacements values distribution through the FEA, and the displacements isolines are presented in Fig.3.

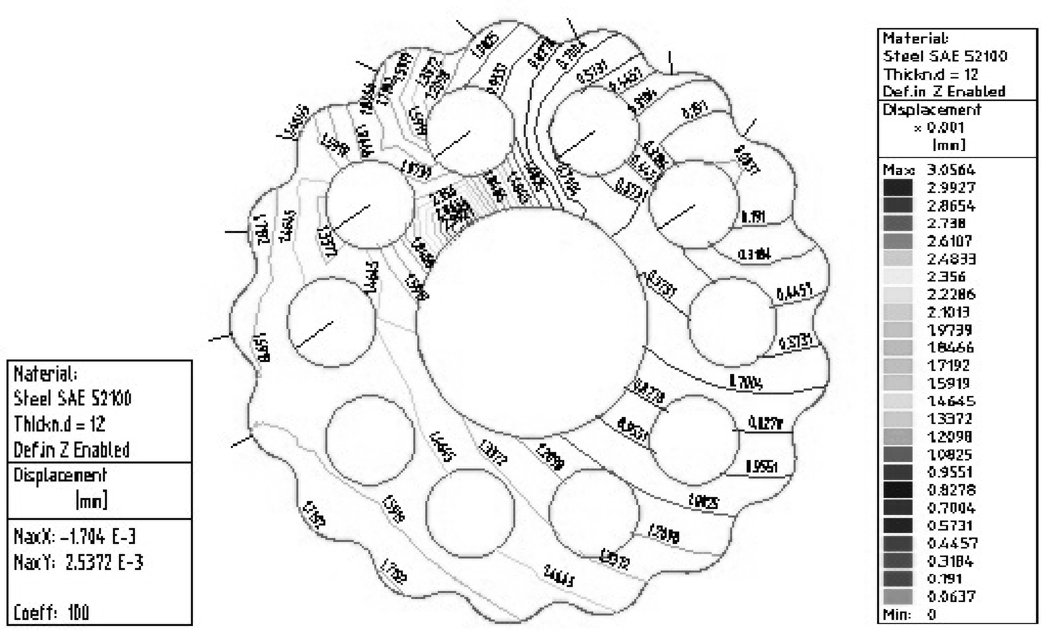


Fig.3 *Displacements isolines on the satellite gear*

The displacements values in the contact points of the satellite gear with the gearing roller teeth are presented in diagram form in Fig.4, and in Fig.5 is point out the relation between the reactions values and the displacements values, also depending on the satellite gear stiffness on radial direction as a result of the holes position in the satellite gear.

The analytical determination of the reaction we have made in two hypotheses [3]:

- with uniform distributed reactions on all roller teeth (curve 3. Fig.6);
- with uniform distributed pressures on the contact points of the satellite gear with the roller teeth (curve 2, Fig.6);

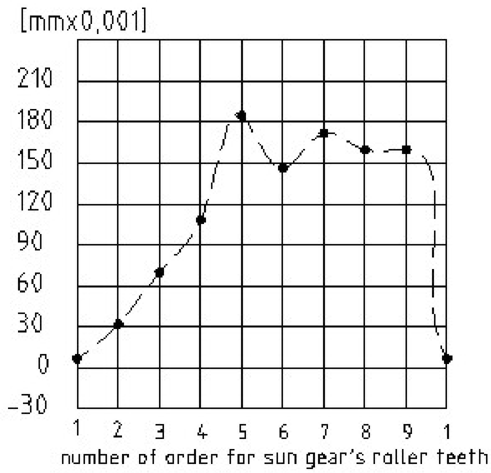


Fig.4 *The diagram of the displacements values in the contact points of gearing roller teeth*

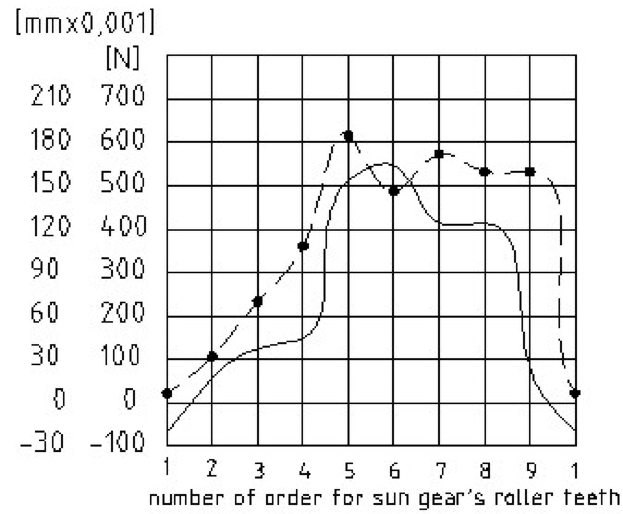


Fig.5 *The diagrams of the reactions and the displacements values in the contact points of the gearing roller teeth*

In the end, we built the diagrams presented in Fig.6 who allows us to compare the values of the reactions resulted by different methods: the curves 3 and 2 obtained in the two previous specified analytical hypotheses and the curve 1 obtained with Finite Element Analysis Method.

The limits values of the displacements and stress on the satellite gear are listed in file .txt presented in Table 1. For solving all special FEA task, we can continue the analysis transferring the 2D model of satellite gear in Ansys program.

4. CONCLUSIONS

The study and the comparison of the satellite gear reactions variations in these cases of analysis allow us to express the following conclusions:

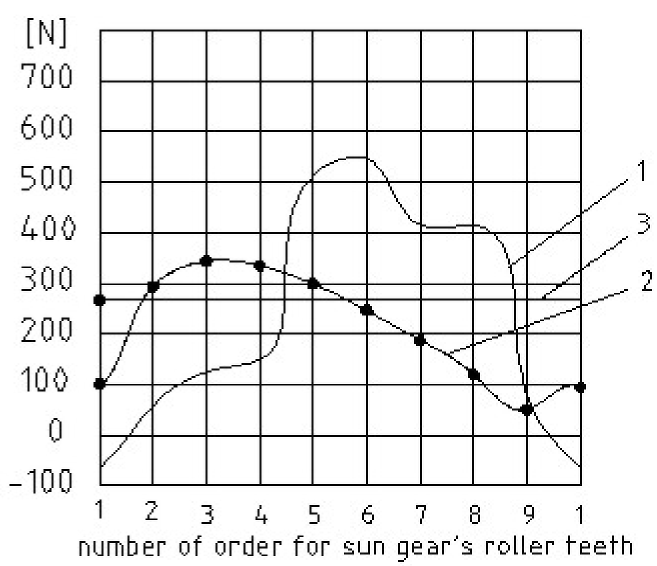


Fig.6 *Diagrams of the reaction variation obtained with analytical (curve 2,3) and FEA methods (curve1)*

- The upper value of the reaction obtain on the gearing roller teeth is located on the middle of the gearing arc (curve 1),
- There are important difference between the reactions values obtained on the roller teeth situated in the ends of the gearing arc;
- On the second half of the gearing arc, the reactions are slightly decreasing;
- In the contact points of the satellite gear with the gearing roller teeth, the opposite direction of the reactions is given by the deformation of the satellite gear.
- The paper shows the particularities of the static behaviour of the planetary gear.
- We propose a model of analysis with Finite Element Method of the contact situation of the satellite gear with the gearing roller teeth and with the gearing thumbs.

Table 1. ***Limits values of the displacement and stress on the satellite gear***

Solution:	FEA-2D	Elastic deformation in Z-axis enabled
Material:	Steel SAE 52100	
Elastic modulus	206843.00	[N/mm^2]
Poisson constant	0.30	
Thickness	12.00	

max./min.values

			Value	Nodes	XY-coord.	
Displacement	max dx	[mm] :	0.8195 * E-3	1790	-26.08,	61.74
	min dx	[mm] :	-1.7042 * E-3	654	-15.28,	21.03
Displacement	max dy	[mm] :	2.5372 * E-3	654	-15.28,	21.03
	min dy	[mm] :	-0.2525 * E-3	897	66.81,	11.07
Displacement	max d	[mm] :	3.0564 * E-3	654	-15.28,	21.03
Von Mises	max svM	[N/mm^2]:	50.8594	1370	-63.90,	20.77
Stress in X-Axis	max sX	[N/mm^2]:	10.4496	1535	-38.93,	49.68
	min sX	[N/mm^2]:	-57.6099	1370	-63.90,	20.77
Stress in Y-Axis	max sY	[N/mm^2]:	7.4559	1521	-36.79,	51.44
	min sY	[N/mm^2]:	-19.0368	1370	-63.90,	20.77
Stress in Z-Axis	max sZ	[N/mm^2]:	0.0000	1	20.73,	-50.10
	min sZ	[N/mm^2]:	0.0000	1	20.73,	-50.10
Shear Stress	max Txy	[N/mm^2]:	6.5172	1620	-12.97,	63.97
	min txy	[N/mm^2]:	-4.1273	1644	-52.08,	42.45
Main Stress	max s1	[N/mm^2]:	13.1984	1536	-38.44,	49.95
	min s1	[N/mm^2]:	-19.0188	1370	-63.90,	20.77
Main Stress	max s2	[N/mm^2]:	1.2099	510	-23.02,	12.09
	min s2	[N/mm^2]:	-57.6279	1370	-63.90,	20.77

5. REFERENCES

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