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INFLUENCE OF GEOMETRICAL PARAMETERS ON RIGIDITY OF THE WORM-GEARING TOOTH

Conf. dr. ing. Daniela GHELASE
Conf. dr. ing. Luiza DASCHIEVICI
Conf. Dr. ing. Niculai HAUK
Universitatea "Dunarea de Jos' din Galati

ABSTRACT

By means of an original numerical method, the authors study the influence of the parameters of the worm-gearing tooth (diametral quotient, radius of profile curvature, profile angle of the worm, number of gear teeth) on its rigidity. The goal of this study is optimization of the geometrical parameters from the viewpoint of rigidity. The computerization simulation was applied to 150 worm-gear drives.

1. Introduction

To study the rigidity, the worm-gear drives were established on the basis of the following suppositions:

1) The worm gear drives have the same overall size, the centre distance being constant, A=315 mm, and they have the same teeth number;

2) The studied worm-gear drives have the following variable parameters:

Table 1

q	m_x [mm]	α [°]	B [mm]
7	5,2066	10	2,341
		15	
		20	
		25	
		30	
8	5,1639	10	2,8392
		15	
		20	
		25	
		30	
9	5,122	10	3,3272
		15	
		20	
		25	
		30	
10	5,0806	10	3,8084
		15	
		20	
		25	
		30	
11	5,04	10	4,282
		15	
		20	
		25	
		30	
12	5	10	4,748
		15	
		20	
		25	
		30	
13	4,9606	10	5,2066
		15	
		20	
		25	
		30	
14	4,9219	10	5,6582
		15	
		20	
		25	
		30	
15	4,8837	10	6,1026
		15	
		20	
		25	
		30	
16	4,8462	10	6,5404
		15	
		20	
		25	
		30	

- diametral quotient q, in accordance with the data presented in the table 1;
- profile angle of the worm α, in accordance with the data presented in the table 1;

3) Axial module of the worm-gearing tooth is given by the relation

$$m_x=2\cdot A/(q+z_2); \quad (1)$$

4) Any worm-gearing is studied in three variants, depending on radius of worm profile curvature:

$R= 1,5\cdot m_x$, $R= 3\cdot m_x$, $R= 4\cdot m_x$;

5) In the table 1 there are the geometrical parameters of the studied gear drives. Every spatial gearing consists of 11 plane-gear drives (pinion-rack drives), that in fact are cross sections perpendicular to worm-gear axis, resulting different widths for the plane-gear drives (B).

2. Influence of diametral quotient on rigidity

On the basis of the table 2, it was obtained the diagram (figure 1) of the rigidity of worm-gearing tooth depending on diametral quotient q, if the profile angle is considered to be constant.

Table 2

q	$R=3\cdot m_x$ [mm]	Maxim rigidity [KN/mm] for α=10°	Minim rigidity [KN/mm] for α=10°	Medium rigidity [KN/mm] for α=10°
7	15,61	1087,027	647,259	867,143
8	15,49	1268,945	805,068	1037,007
9	15,36	1453,498	977,226	1125,362
10	15,24	1627,64	1114,246	1387,443
11	15,12	1792,178	1303,839	1548,008
12	15	1974,295	1452,423	1713,359
13	14,88	2136,667	1604,346	1870,006
14	14,76	2290,487	1759,527	2025,007
15	14,65	2414,695	1913,697	2164,196
16	14,53	2552,447	2059,235	2305,841

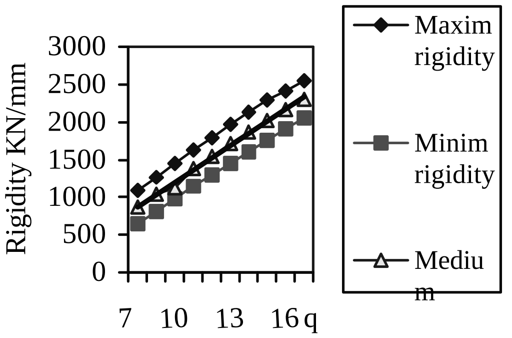

Figure 1. Rigidity depending on q

As may be seen, the rigidity of worm-gearing tooth is increasing at the same time with the diametral quotient. The explication is simple: if the diametral quotient increases, then worm diameters increase too. It is known that the number of cross sections is constant. Hence, the width of plane gearing will increase, resulting an increasing of rigidity.

3. Influence of radius of profile curvature

The radius of profile curvature is depending on the axial module, so every studied gearing has another radius of profile curvature. As may be seen in tables 3and 4 for a certain diametral quotient q, the radius of profile has risen 1,33 times and rigidity has risen too.

Table 3

q	m_x [mm]	Maxim rigidity [KN/mm] for $R=3\cdot m_x$ and α=10°	Maxim rigidity [KN/mm] for $R=4\cdot m_x$ and α=10°
7	5,2066	1087,027	1231,259
8	5,1639	1268,945	1454,918
9	5,1220	1453,498	1660,191
10	5,0806	1627,640	1874,163
11	5,0400	1792,178	2052,678
12	5,0000	1974,295	2246,004
13	4,9606	2136,667	2421,314
14	4,9219	2290,487	2602,595
15	4,8837	2414,695	2772,391
16	4,8462	2552,447	2905,037

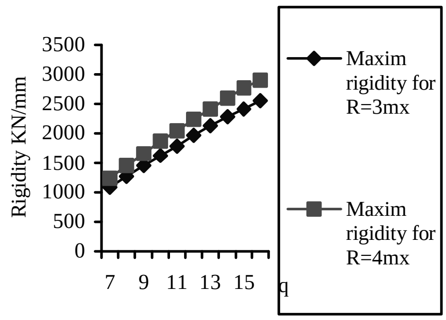

Figure 2. Maxim rigidity depending on radius R

Table 4

q	m_x [mm]	Minim rigidity [KN/mm] for $R=3\cdot m_x$ and α=10°	Minim rigidity [KN/mm] for $R=4\cdot m_x$ and α=10°
7	5,2066	647,259	930,568
8	5,1639	805,068	1134,918
9	5,1220	977,226	1333,864
10	5,0806	1147,246	1530,545
11	5,0400	1303,839	1707,283
12	5,0000	1452,423	1880,702
13	4,9606	1604,346	2066,864
14	4,9219	1759,527	2241,540
15	4,8837	1913,697	2391,344
16	4,8462	2059,235	2458,946

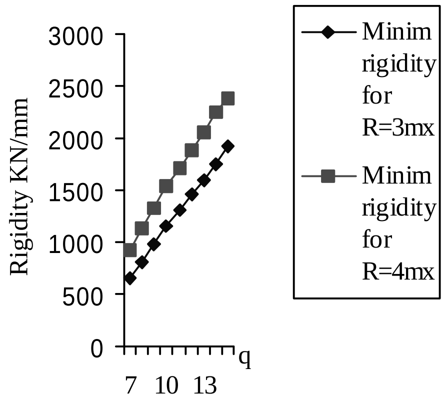

Figure 3. Minim rigidity depending on radius of profile curvature R

If q and α are constant, while the radius of profile curvature is increasing the tooth dimensions are changing, especially the tooth depth, so that the rigidity will increase (figures 2 and 3).

4. Influence of worm profile angle

The influence of worm profile angle α on rigidity is presented in the table 5 and figure 4. The conclusion is that, while the profile angle is increasing, the worm-gearing rigidity is decreasing because the plan gear drives width B is decreasing.

Table 5

α [°]	Maxim rigidity [KN/mm] for $R=3\cdot m_x$ and q=7	Minim rigidity [KN/mm] for $R=3\cdot m_x$ and q=7	Medium rigidity [KN/mm] for $R=3\cdot m_x$ and q=7
10	1087,027	647,259	867,143
15	930,087	442,790	686,438
20	817,641	280,1511	548,896
25	747,323	157,58	402,651
30	710,374	77,53	393,952
30	710,374	77,53	393,952

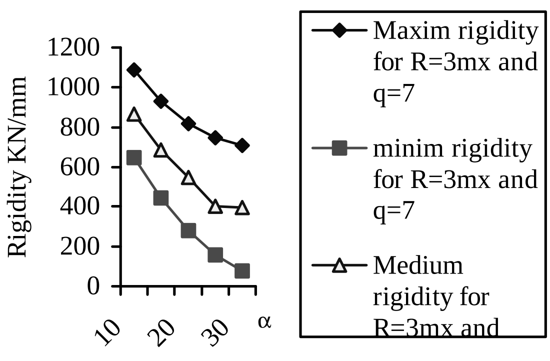

Figure 4. Rigidity depending on α, for q=7

5. Influence of number of gear teeth on rigidity

The influence of the number of gear teeth on rigidity was studied for 4 worm-gear sets. In the table 6 there are geometrical parameters of those worm-gear sets. The results of the study are presented in the table 7 and figure 5. The conclusion is that, while the number of gear teeth is increasing, the worm-gearing rigidity is decreasing because the plan-gear drives width B is decreasing.

Table 6

Worm-gearing	z_1	z_2	q	m_x [mm]	α [°]	R[mm]	B [mm]
I	1	53	10	10	20	35	7,498
II	1	80	10	7	20	35	5,248
III	1	90	10	6,3	20	35	4,723
IV	1	169	11	3,5	20	35	2,973

Table 7

z_2	Maxim rigidity [KN/mm]	Minim rigidity [KN/mm]	Medium rigidity [KN/mm]
53	2267,385	1215,140	1741,262
80	1727,633	1132,201	1429,917
90	1581,896	1079,696	1330,796
169	1055,990	853,826	954,908

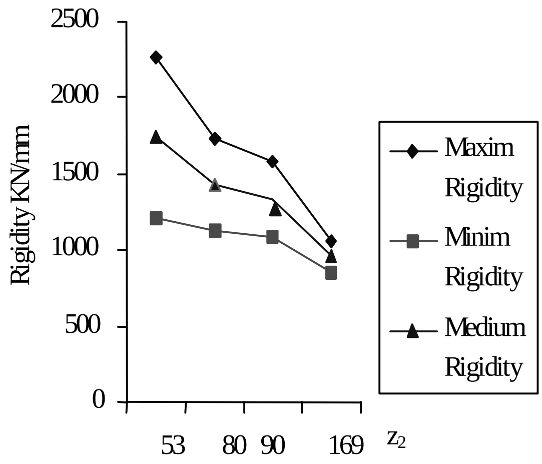

Figure 5. Rigidity depending on z_2

Conclusions

The influences of the geometrical parameters on the rigidity of the worm-gearing tooth are:

1. The rigidity of worm-gearing tooth increases if:

- the diametral quotient increases;

- the radius of profile curvature increases;

2. The rigidity of worm-gearing tooth decreases if:

- the profile angle increases;
- number of gear teeth increases;

3. The proposed approach allows the geometry optimization and study of the meshing for any types of the cylindrical worm-gearing and for spur gearing and bevel gearing;
4. This study leads to increasing of the accuracy of the machine-tool or robot linkages.

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