

Parametric Influences in the ISO Project Concerning Worm Gear Rating

by: M. Octrue, Centre Technique des Industries Mecaniques

American Gear Manufacturers Association



TECHNICAL PAPER

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Michel Octrue, Centre Technique des Industries Mecaniques

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Abstract

The author analyses the influence of different parameters taking into account in the CD ISO 14521 for worm gear rating for the different criteria such as:

- efficiency,
- wear load capacity,
- surface durability (Pitting)
- deflection
- tooth root strength

The influencing parameters are divided in different categories, like intrinsic parameters to the worm gear like geometry or materials, environmental parameters like lubricants and temperature, external parameters like loading conditions, and driving and driven machines.

Some criteria are compared to analytical methods and experimental results.

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American Gear Manufacturers Association
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PARAMETRIC INFLUENCES IN THE ISO PROJECT CONCERNING WORM GEAR RATING

By Dr Michel OCTRUE – CETIM - France

1-Introduction

In the framework of ISO Technical committee TC60, a new work item concerning the calculation of load capacity of worm gear is in process since 4 years. The future reference of the standard ISO 14521: load capacity calculation of worm gear. This standard is based on DIN 3996 which has been adopted in Germany in September 1998.

The following conditions that can limit the rated load capacity :

- **wear** : such damage usually appears on the tooth flanks of bronze wormwheels
- **pitting** : this form of damage may appear on the flanks of wormwheel teeth. Its development is strongly influenced by the load transmitted and the load-sharing conditions.
- **tooth breakage** : shear failure of wormwheel teeth or worm threads can occur when teeth become thin due to wear or overload. Worm thread and worm shaft breakage: shaft breakage can occur as a result of bending fatigue or overload.
- **worm shaft deflection** : excessive deformation under load modifying contact pattern between worm and worm wheel.
- **scuffing** : this form of damage often appears suddenly. It is strongly influenced by transmitted load, sliding velocities and the conditions of lubrication.
- **working temperature** : when excessively high working temperature leads to accelerated degradation of the worm gear lubricant.

Among this, ISO 14521 defines criteria for: wear, pitting, tooth breakage of worm wheel, worm shaft deflection.

Table 1 indicates the relationship between different forms of capacity limits in combination with speed and torque.

In order to illustrate the behaviour of ISO 14521, this paper :

- presents result calculations based on 3 worm gears sets which are those used in our laboratory for testing,
- presents synthesis of influencing parameters for each criteria calculation, with comments, and an identification of the best choice for some parameters.

2-Principles of calculations in ISO 14521

As it has been introduced, the calculation of load capacity is based on 4 criteria, which are linked together as follows :

- criteria for pitting and criteria for worm shaft deflection are independent of others,
- criteria for wear and criteria for tooth breakage of worm wheel are dependent because the reduction of worm wheel tooth thickness by wear is taken into account for the calculation of shear stress at tooth root.
- criteria for wear is function of oil film thickness, which depends on oil film temperature, so the calculation of different type of power losses in order to determine the wheel bulk temperature, is the first step for wear calculation.

Note: This concept of wheel bulk temperature calculation is very important in ISO 14521. It must be considered by new users of this standard. At design stage it is not always easy to evaluate all data for such calculation.

3-Definition of gear data

Since more than 10 years CETIM undertook endurance tests for worm gears in order to check their behaviour according to wear. Three bench tests have been set-up, with a centre distance of 125 mm, for 3 different gear ratios: 1/40, 3/31, 5/24 (see **Table 2** and **Table 3**).

4-Sensitivity of ISO 14521 to geometry

In order to isolate the influence of geometry on the zone of contact and the lines of contact, it has defined non-dimensional parameters (see Table 4):

- p_m^* , for the mean Hertzian stress,
- h^* , for the mean lubricant film thickness
- s^* , for the mean slip path.

Table 1 - Most significant factors

	Wear	Pitting	Tooth-Breakage	Worm shaft deflection	Scuffing	Excessive wear	Low efficiency
Hertzian pressure	X	X	X		X	X	X
Oil film thickness	X	X			X	X	X
Worm speed	X	X			X	X	X
Oil	X	X			X	X	X
Contact Pattern	X	X	X		X	X	X
Worm surface roughness	X	X			X	X	X
Shearing value			X				

Table 2-Geometrical data of worm gears

	A	B	C
Center distance [mm]	125	125	125
Gear ratio $u=z_1/z_2$	1/40	3/31	5/24
Axial module [mm]	4.95	6.45	8.36
Lead angle [°]	5.4375	21.1369	40.2592
Normal pressure angle [°]	21.81	20.65	25
Worm PROFILE	A	A	A
Worm wheel face width [mm]	45	45	45
External diameter of worm wheel [mm]	220	220	220

Table 3-Materials and lubricant

Worm material	Case hardened steel
Worm wheel	Bronze with 12 % of tin an x% of Nickel.
Lubricant	Synthetic Oil : Polyglycol SHELL TIVELA A - 122 Cst at 40°C

Table 4 – Non-dimensional parameters calculation

	Geometry
p_m^* , parameter for the mean Hertzian stress	p_m^* (Type of profile, q_1 , z_2 , x_2 , b/m_{x1} , u)
h^* , parameter for the mean lubricant film thickness	h^* (Type of profile, q_1 , z_2 , x_2 , b/m_{x1} , u)
s^* , parameter for the mean slip path	s^* (Type of profile, γ_1 , u)