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Investigation of load carrying capacity of asymmetric high contact ratio spur gear based on load sharing using direct gear design approach

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ABSTRACT

The Direct Gear Design® approach is one of the many gear designing methods available to improve load carrying capacity of the gear pairs. For customized gear pairs, the direct gear design approach is more advantageous over conventional design. In this paper, a parametric study is carried out for asymmetric high contact ratio spur gears based on load sharing method to determine the improvement in load carrying capacity. A finite element model for multi-pair contact is adopted to determine the non-dimensional fillet and contact stresses which quantify the load carrying capacity of the gear pairs. The results of direct designed symmetric and asymmetric high contact ratio spur gears are compared with the conventional symmetric high contact ratio spur gears. Also, the influence of gear parameters such as addendum pressure angle, gear ratio, teeth number and backup ratio of non-dimensional stresses is analyzed in detail. The results show significant improvement in gear pair performance for all parameters analyzed.

1. Introduction

In general, the load carrying capacity of gear drives is affected by the fillet and contact strength of the gear tooth [1]. The insufficient fillet strength leads to tooth fracture whereas; the insufficient contact strength leads to surface failures such as wear, pitting, scoring and plastic flow.

Direct Gear Design® approach is one of the ways to improve load carrying capacity of the gear pairs. For customized (non-standard) gears, the direct gear design approach is more advantageous over conventional design to improve the fillet and contact strength of the gear tooth. In this paper, a non-standard high contact ratio (HCR) asymmetric spur gear designed through direct gear design approach is used to determine the improvement in load carrying capacity. Contact ratio (ε) is the average number of teeth in mesh during the gear contact. When the contact ratio, $\varepsilon > 2$, it is called as high contact ratio gears. The typical asymmetric HCR spur gear is shown in Fig. 1.

In the Direct Gear Design® approach, the gear tooth geometry is first defined primarily based on the operating conditions of the gear drives. And then, the tool (rack cutter) parameters such as module, pressure angle, addendum, dedendum and cutter tip radius are derived from the gear tooth geometry [2,3]. Elkholy [4] presented the analytical model of HCR spur gear to find the load sharing ratio considering mesh tooth stiffness for one mesh cycle. Lewicki [5] studied the effect of rim thickness on spur gears and found the crack propagation direction through the experiments and finite element technique. Litvin et al. [6] presented a finite element method to find the bending and contact stresses for a double crowned pinion, which reduces the localization of bearing contact and transmission errors. Mohanty [7] developed an analytical model to estimate the load sharing based tooth stiffness

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Nomenclature

a_o	center distance (mm)
a_w	working center distance (mm)
A	cutter tip radius (mm)
b	face width (mm)
$C_{\min}$	minimum clearance (mm)
D_{bc}	diameter of base circle at coast side (mm)
D_{bd}	diameter of base circle at drive side (mm)
D_{tip}	tip circle diameter (mm)
E	Young's modulus (GPa)
F_n	normal load (N)
h_{ar}	addendum of rack cutter
h_{fr}	dedendum of rack cutter
i	gear ratio
k	asymmetric factor
m	module (mm)
m_r	module of rack cutter (mm)
m_a	top land thickness coefficient
p_b	base pitch
r_f	root circle radius (mm)
r_w	working circle radius (mm)
R	radius of curvature
T_{wr}	rack cutter tooth thickness (mm)
v_c	coast side profile angle (degree)
v_d	drive side profile angle (degree)
x	addendum modification factor
X	distance between a contact point and the pitch point at any instance (mm)
z	number of teeth
α_o	pressure angle (degree)
α_w	Working pressure angle (Degree)
α_{ad1}	addendum pressure angle of pinion (degree)
α_{ad2}	addendum pressure angle of gear (degree)
ε_c	coast side contact ratio
ε_d	drive side contact ratio
μ	Poisson's ratio
$(\sigma_t)_{\max}$	maximum fillet stress (MPa)
$(\sigma_H)_{\max}$	maximum contact stress (MPa)
σ_{fu}	non-dimensional fillet stress
σ_{Hu}	non-dimensional contact stress

Subscripts

c	coast side
d	drive side
1	pinion
2	gear

Abbreviations

APDL	Ansys parametric design language
AGMA	American Gear Manufacturing Association
ISO	International Organization for Standardization
FE	finite element
FHPDTC	first highest point of double tooth contact
FLPDTC	first lowest point of double tooth contact
HPTC	highest point of tooth contact
HPSTC	highest point of single tooth contact
LPTC	lowest point of tooth contact