TITLE

MAXIMUM TORQUE OF COMBINATION THREATS FOR SPUR GEAR BASED ON AGMA AND JGMA STANDARDS

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ABSTRACT

This thesis is an approach to investigate the transformation curve of gearing safety. Two types of tooth failures are known to happen to spur gears. There are tooth bending failure (breakage) and tooth surface pitting failure. The focus of this study however will be on the JGMA and AGMA standards of gearing. Different methods were used to gather relevant data from both standards. JGMA data were gathered from a source in the internet while AGMA data were calculated with the aid of Autodesk Inventor spur gear component generator 2013. The most important data is the allowable torque applied on the gear tooth which can be distinguished into causing either one of the tooth failures mentioned above. Several materials selected from the JGMA and AGMA standards with high value of allowable contact stress compared to its allowable bending stress have a transformation curve from surface durability to bending strength when its torque values are plotted against number of teeth. This allows the forming of a combination threats curve for the material. The curves are useful in determining the maximum torque that can be applied on the spur gear before failures occur. The threat combination curves are then further developed into charts that include other parameters like power, angular velocity and pitch diameters.

ABSTRAK

Tesis ini merupakan satu pendekatan untuk mengkaji lengkung perubahan keselamatan bagi gear taji. Dua jenis kegagalan yang boleh berlaku pada gigi gear taji telahpun dikenalpasti. Kegagalan tersebut adalah *tooth bending failure* (patah) dan *tooth surface pitting failure* . Fokus kajian ini walabagaimanapun adalah kepada standard gear JGMA dan AGMA sahaja . Kaedah yang berbeza yang digunakan untuk mendapatkan data yang relevan dari kedua-dua standard. Data JGMA telah dikumpulkan dari sumber di internet manakala data AGMA dikira dengan bantuan *Autodesk Inventor spur gear component generator 2013*. Data yang paling penting ialah daya kilasan maksimum yang dikenakan pada gigi gear yang boleh dibezakan kepada daya yang akan menyebabkan salah satu daripada kegagalan gigi yang dinyatakan di atas . Beberapa bahan yang dipilih dari standard JGMA dan AGMA dengan nilai *allowable contact stress* yang tinggi berbanding dengan *allowable bending stress* mempunyai lengkung transformasi daripada *surface durability* kepada *bending strength* apabila nilai kilasannya diplot terhadap jumlah gigi gear. Ini membolehkan pembentukan lengkung ancaman gabungan untuk bahan-bahan tersebut. *(combination threats curve)* . Lengkung ini adalah berguna dalam menentukan daya kilas maksimum yang boleh digunakan pada gear taji sebelum kegagalan berlaku. Lengkung ancaman gabungan ini kemudiannya akan dibangunkan seterusnys ke dalam bentuk carta yang akan menggabungkan parameter- parameter lain seperti kuasa , halaju sudut dan *pitch diameter* gear.

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LIST OF SYMBOLS

P_d = Diametral pitch

m = module

N = Number of teeth

D_p = Pitch diameter

AGMA standards

σ = Gear bending stress

$\sigma_{allowable}$ = Gear bending endurance strength

S_F = Bending factor of safety (AGMA)

W_t = transmitted load, kN

H = power, kW

V = pitch line velocity, mm/s

K_o = Overload factor

K_v = Dynamic factor

K_s = Size factor

F = Facewidth, mm

K_m = load distribution factor

K_B = Rim Thickness factor

J = Geometry factor for bending strength

S_t = Gear bending strength, MPa(value depends on gear materials)

Y_N = Stress cycle factor for bending stress

K_T = Temperature factor

K_R = Reliability factor

σ_c = Gear contact stress

$\sigma_{c,allowable}$ = Gear contact endurance strength

S_H = Wear factor of safety (AGMA)

C_p = elastic coefficient, $\sqrt{N/mm^2}$

C_f = Surface condition factor, used $C_f = 1$

d_p = Pitch diameter of pinion, mm

I = Geometry factor for pitting resistance

Z_N = Stress cycle life factor , Z_W = Hardness ratio factors for pitting resistance

S_c = contact fatique strength, MPa(value depends on gear material)

C_H = Hardness ratio factors for pitting resistance

JGMA standards

F_t = tangential force at pitch circle (kgf)

P = power (KW)

T = Torque (kgf. m)

d_b = working pitch diameter (mm)

n = Rotational speed (rpm)

v = Tangential speed of workng pitch circle (m/s)

F_{tlim}= Allowable tangential force at the working pitch circle.

σ_F = Actual bending stress at the root

σ_{Flim}= Allowable bending stress at the root

b = facewidth (mm)

Y_F = Tooth profile factor

Y_ε = Load sharing factor

K_L = Life factor

K_{FX} = Size factor of root stress, normally 1.00

K_V = Dynamic load factor

K_O = Overload factor

S_F = safety factor for bending failure

Y_β = Helix angle factor (1.00 for spur gears)

M_n = Normal module

σ_H = Actual Hertz stress

σ_{Hlim} = Allowable Hertz stress

b_H = facewidth (mm)

d_{01} = Pitch diameter of pinion (mm)

i = gear ratio

Z_H = Zone factor

Z_M = Material factor

Z_ε = Contact ratio factor

Z_β = Helix angle factor

K_{HL} = Life factor

Z_L = Lubricant factor

Z_R = Surface roughness factor

Z_V = Lubrication speed factor

Z_w = Hardness ratio factor

K_{HX} = Size factor

$K_{H\beta}$ = Load distribution factor

K_V = Dynamic load factor

K_O = Overload factor

S_H = Safety factor for pitting

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CHAPTER 1

1.1 INTRODUCTION

Gears are defined as toothed wheels or multi-lobed cams which transmit power and motion from one shaft to another by means of successive engagement of teeth [1]. Its popularity and usage in various type of machinery as a transmission component is mainly due to the fact that it is a positive drive and hence the velocity ratio is constant, it can transmit much larger power as compared to belt and chain drive, it is especially suitable for transmitting power at low velocity and most of all the transmission efficiency is very high. Gears range in size from miniature instrument installations, such as watches, to large powerful gears used in automobiles and turbine drives for ocean liners.

There are many types of gears and it is common to classify them into 3 categories; parallel axes gears, intersecting axes gears, and nonparallel and nonintersecting axes gears. **Table 1.1** below lists some examples of the gear types available by axes orientation.

Table 1.1 Types of gears and their categories

Categories of gears	Types of gears
Parallel axes gears	Spur gear, Spur rack, Internal gear, Helical gear, Double Helical gear (Herringbone gear)
Intersecting axes gears	Straight bevel gear, Spiral bevel gear
Nonparallel and nonintersecting	Screw gear, Worm gear

The gear types in Table 1.1 are further explained below: (From Ref.[2])

a) Spur Gear – This is a cylindrical shape gear, in which the teeth are arranged parallel to the axis. It is the most commonly used gear with a wide range of applications and is the easiest to manufacture.

Figure 1.1: Spur gear

b) Spur Rack – This is a linear shaped gear which can mesh with a spur gear with any number of teeth. The spur rack is a portion of a spur gear with an infinite radius.

Figure 1.2: Spur Rack

c) Internal gear – This is also a cylindrical shaped gear, but with the teeth inside the circular ring. It can mesh with a spur gear. Internal gears are often used in planetary gear systems.

Figure 1.3: Internal gear

d) Helical gear – This is a cylindrical shaped gear with helicoid teeth. Helical gears can bear more load than spur gears, and work more quietly. They are widely used in industry. A disadvantage is the axial thrust force caused by the helix form.

Figure 1.4: Helical gear

e) Double helical gear (Herringbone gear) – A gear with both left-hand and right-hand helical teeth. The double helical form balances the inherent thrust forces.

Figure 1.5: Herringbone gear

f) Straight bevel gear – This is a gear in which the teeth have tapered conical elements that have the same direction as the pitch cone base line. The straight bevel gear is both the simplest to produce and the most widely applied in the bevel gear family.

Figure 1.6: Straight Bevel gear

g) Spiral bevel gear – This is a bevel gear with a helical angle of spiral teeth. It is much more complex to manufacture, but offers higher strength and less noise.

Figure 1.7: Spiral bevel gears

h) Screw gear – A pair of cylindrical gears used to drive non-parallel and nonintersecting shafts where the teeth of one or both members of the pair are of screw form. Screw gears are used in the combination of screw gear/screw gear, or screw gear/spur gear. Screw gears assure smooth, quiet operation. However, they are not suitable for transmission of high horsepower.

Figure 1.8: Screw gear

i) Worm gear – Worm gear pair is the name for a meshed worm and worm wheel. An outstanding feature is that if offers a very large gear ratio in a single mesh. It also provides quiet and smooth action. However, transmission efficiency is poor.

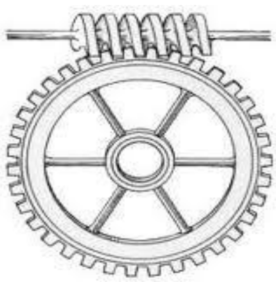

Figure 1.9: Worm gear

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