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The Analysis and Modification of Bevel Gear Design

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***Abstract* - These applications are explain the design the bevel gear and dimension pacification. This investigation gives a detailed approach to spiral gear design and analysis. It's have a involving modern design, specific character, specific material with consideration of analysis of force and its mechanical properties these approach for modern bevel gear design developing the tooth profiles with modified the shape and improves the efficiency of power transmission. This study also analyzes the general characteristics of spherical bevel gears and discusses the issue of bevel-gear standardization.**

***Index Terms*- bevel gear, modern design, specific character, mechanical properties.**

I. INTRODUCTION

The bevels are used to transmit power at a constant velocity ratio between two shafts whose axes intersect at a certain angle. The pitch surfaces for the bevel gear are frustums of cones.

A bevel gear is a gear element that efficiently transfer power and motion at an intersection of multiple axes. Some bevel gears have tooth profiles with benefits similar to those found in involute type gears most frequently used in parallel axis gear systems. This gear can be meshed together correctly only if they are fitted to parallel safts. The main reason for the popularity of spur gear is their simplicity in design and manufacturing. The two parameter i.e. tip radius and tooth widths which play a key role gear design are studied. [1].

The tooth meshing on another gear of non rotating parts is called rack. When it a rotation it provide transmission in analogous to the wheels in pully. It is the cylindrical shaped its teeth are parallel in axis. Its wide range of application most commonly used. [2]. A gear is a rotating machine part having cut teeth. Which is meshing the gear teeth to transmit the torque, a geared device can be change the speed, direction of power sources and magnitude.[3].

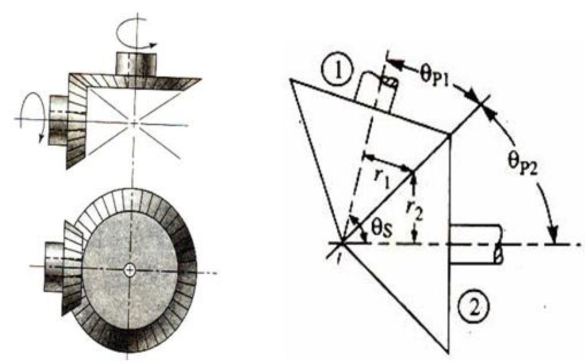

Fig.1. Bevel Gear

II. CLASSIFICATION OF BEVEL GEARS

Classified depending upon the angle between the shafts and the pitch surfaces-

A) Miter gears: When equal bevel gears (having equal teeth and equal angles) contact two shaft whose axes intersect at right angles as shown, then they are known as miter gear.

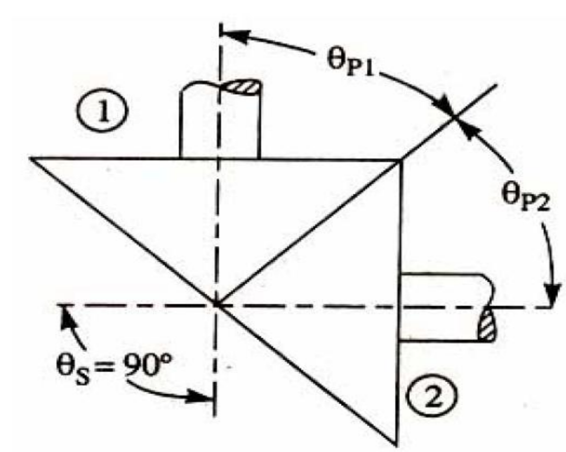

Fig.2. Miter gears

B) **Angular bevel gears:** when the bevel gears connect two shaft whose axes intersect at an angle other than a right angle, then they are known as angular bevel gears.

C) **Crown bevel gears:** when bevel gears connect two shafts whose axes intersect at an angle greater than a right angle and the bevel gears has a pitch angle of 90□□then it is known as crown gear. a The crown gear corresponds to a rack in spur gearing as shown.

D) **Internal bevel gears:** when the teeth on the bevel gear are cut on the inside of the pitch cone then they are known as bevel gears.

III. DESIGN OF BEVEL GEAR

In order to design build and discuss gear drive systems it is necessary to understand the terminology and concepts associated with gear systems.

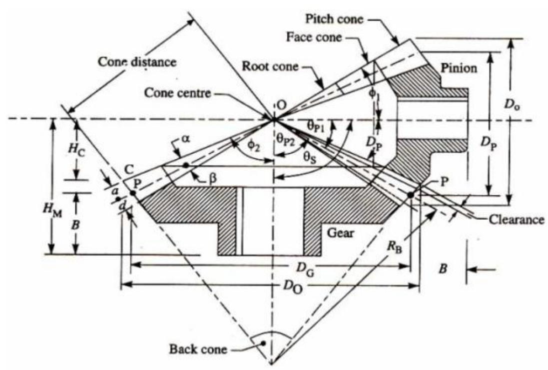

Figure 2 . Bevel gear nomenclature in the axial plane [3]

A sectional view of two bevel gears in mesh is as shown in figure. The following terms important from the subject point of view.

- **Pitch cone:** It is a cone containing the pitch elements of the teeth.
- **Cone centre:** It is apex of the pitch cone. It may be defined as that point where the axes of two mating gears intersect each other.
- **Pitch angle:** It is angle made by the pitch line with the axis of the shaft. It is denoted by (i.e. $\delta 1$ & $\delta 2$) .
- **Cone distance:** It is the length of the pitch cone element. It is also called as a pitch cone radius. It is denoted by ‘OP’ mathematically cone distance or pitch cone radius.

=OP= <u>pitch radius</u> = <u>$D_P/2$</u>
= <u>$D_G/2$</u>
$\sin O_p$ $\sin O_{p1}$
$\sin O_{p2}$

- **Addendum angle:** It is the angle subtended by the addendum of tooth at the cone centre. It is denoted by θa. Mathematically addendum angle

$$\tan \theta a = \frac{2h_{a1}Sin\delta_1}{d_1}$$
$$= \frac{2h_{a1}Sin\delta_1}{d_2}$$

- **Dedendum angle:** It is the angle subtended by the Dedendum of the tooth at the cone centre. It is denoted by θd. Mathematically,

$$\tan \theta d = \frac{2h_{f1}Sin\delta_1}{d_1}$$
$$= \frac{2h_{a1}Sin\delta_1}{f_2}$$

s Where, ha1, ha2 = addendum of the pinion and gear respectively, mm

hf1, hf2 = dedendum of pinion and gear respectively, mm

- **Face angle** It is angle subtended by the face of the tooth at the cone centre, the face angle is equal to the pitch angle plus addendum angle.
- **Root angle:** It is the angle subtended by the root of the tooth at the cone centre. It is equal to the pitch angle minus dedendum angle.
- **Back cone:** (Normal cone) it is the imaginary cone perpendicular to the pitch cone at end of the tooth.
- **Crown height:** It is the distance of the crown point C, from the cone centre O. parallel to the axis of the gear. It is the denoted by C
- **Mounting height:** It is the distance of the back of the boss from the cone centre. It is denoted by ‘ m’
- **Pitch diameter:** It is the diameter of the largest pitch circle..
- **Outside or addendum cone diameter**: it is the maximum diameter of the teeth of gear. It is

equal to the diameter of the blank from which the gear can be cut.

Mathematically outside dia ,

$dO1 = d1 + 2ha1$, Cos □1

$dO2 = d2 + 2ha2$, Cos □2

Proportions of Bevel gears:

The proportion for the bevel gear may be taken as

(i) Addendum:

a = 1.0 m

(ii) Dedendum:

d=1.2 m

(iii) Clearance

= 0.2 m

(iv) Working depth

= 2.0m

(v) Tooth thiknes

= 1.5708

Formative or Equivalent number of teeth for Bevel Gears: (Tredgold's approximation)

Ze = Z/Cos□

IV. GEAR LIFE CALCULATION

Per the recommendations of the AGMA, Miner's rule is used to calculate the effects of cumulative fatigue damage under repeated and variable intensity loads. Miner's rule is based on the theory that the portion of useful fatigue life used up by a number of repeated stress cycles at a particular stress is proportional to the total number of cycles in the overall fatigue life of the part. Using this hypothesis, Miner's rule assumes that the damage done by each stress repetition at a given stress level is equal, and that the first stress cycle at a uniform stress level is as damaging as the last [5].

V. BASIC THEORY OF GEAR SIMULATION

As for the gear pair, the meshed gears will not only have to meet the the elasticity equation, but also have to satisfy the displacement of embedded conditions in the normal direction of the meshing point and obey the law of coulomb in the tangent direction. According to the contact statement, the contact surfaces can be divided into three kinds of boundary conditions as long as the input torque of driving gear does not change, namely the continuous state, the sliding state and the separation state. The gear pair can be divided into the drive and the driving gear, which are two separate objects. The finite element equations of the two gears can be established in the global coordinate. The equations are as follows:

$$K_1U_1=P_1R1$$
$$K_2U_2=P_2R_2 \qquad [6]$$

Where $K1$, $K2$ are the rigidity matrixes of the drive and the driving gear, $U1$, $U2$ are the displacement vectors of the drive and the driving gear, $P1$, $P2$ are the load vectors force on the drive and the driving gear, $R1$, $R2$ are the contact load vectors.

VI. ISOMETRIC MODIFICATION OF BEVEL GEAR

Isometric modification, as the name implies, is a method of axial modification of the standard tooth with the aim to create a new surface in normal direction [7,8].

The new surface will contact with the standard tooth instead of the original one. Therefore, the contact area of the gear can be controlled by both the position and the size of isometric modification. Fig.(**1**) is the schematic diagram of isometric modification. As is shown in Fig.(**1**) is the non-modified tooth surface, is the modified tooth surface, *p* is a point in surface □and point *p* is in surface , h stands for the size of modification, that is, the distance between P and *p*'.

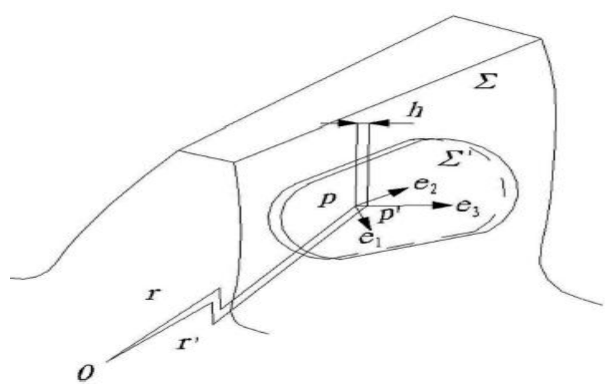

Fig. (1). *Schematic diagram of isometric modification.*

VII. STRENGTH OF BEVEL GEARS:

The strength of a bevel gear tooth is obtained in a similar way as discussed in the previous articles. The modified form of the lewis equation for the tangential tooth is given as follows.

$=F_t = (\sigma_d \times c_v)\ b\ \pi\ m\ y^1 (\frac{L-b}{L})$

y^1 = lewis form factor based on formative or equivalent number of teeth

L= Slant height of pitch cone (or cone distance)

$= \frac{1}{2}\sqrt{d_1^2 + d_2^2}$

Where d_1 and d_2 are the pitch circle diameter on the larger diameter of pinion and gears respectively

(i) The factor i.e. $\frac{L-b}{L}$ may be called as bevel factor

(ii) For satisfactory operation of bevel gears the face width should be from 6m to 10m. also ratio L/b should not exceed 3, (i.e. b$\leq L/3$) for this the number of teeth in the pinion must not be less than $\frac{48}{\sqrt{1+(vR)^2}}$

(iii) The dynamic loads for bevel gears may be obtained in the same similar manner as discussed for spur gears.

(iv) The static tooth load or endurance strength of the tooth for bevel gears is given by

$= F_e = \sigma_e b\ \pi m y^1\ (\frac{L-b}{L})$

The value of flexural endurance limit σ_e may be taken from table

(v) The maximum or limiting load for wear for bevel gears is given by

$= F_w = \frac{D_1\ bQ_e k}{Cos\ \delta_1}$

Where

$D_1\ bQ_e k$ Have usual meanings as discussed in spur gears except that Q_e is based on formative or equivalent number of teeth such that,

$Q = \frac{2\ Ze_2}{Ze_2 + Ze_1}$

VIII. CONCLUSION

This paper performed a comparative analysis of bevel gears, through the combination of both experience and the traditional theory of gear modification, the concept of isometric modification was proposed. By selecting the appropriate modification size and modification location, tooth deformation would be compensated and the stress distribution would be controlled in the central part of tooth.

A short overview of the major modification was given. Unloaded tooth contact analysis of the gears modified in profile and lead (lengthwise) directions was performed, and compared to the actual forged gears. The shape and position of the actual and predicted contact patterns were in good agreement, verifying the proposed procedure.

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