

Study On The Effect Of Spur Gear On Mechanical Application- A Comprehensive Review

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Abstract

The gears generate high stresses in the mating positions over the teeth when transmitting the power as they alter the rotation rate of the machine shaft. The object of this study is to determine the magnitude of the stresses on a spur gear used in the lathe machine for operations such as boring, facing. The friction power losses in spur gears can be measured as the integral, multiplied by the friction coefficient and the elemental slipping, of the normal load along the entire contact line. A full analysis of the effect on efficiency of the design parameters (number of teeth, gear ratio, pressure angle, addendum shift coefficient, etc.

Keywords: Micro pitting, EHL model, design parameters, spur gears.

1. Introduction

Gears are toothed wheels used for transmitting motion and power from one point to another point. A circular body of cylindrical shape or that of the shape of frustum of a cone and of uniform small width, having teeth of uniform formation, provided on its outer circumferential surface is called a gear or toothed gear or toothed wheel. Gear drive has some advantages compared than flat, belt drive. They are i). There is no slip and velocity ratio remains constant, ii). Occupation of space or utilization of space is very less, iii). Whenever the larger power is transmitted where the gear drive is used and it is a positive drive. iv). the efficiency of the gear system is very high. Generally gears are used in automobiles, turbines, low speed applications and also high speed application. The classification of gears is as shown the Fig 1. Day by day application of gear drive system is increased because of their characteristics so essential to learn about gear drive system. In

general, efficiency of the gear drive system depends upon the design parameters but not only depends on design parameters but also lubricant properties and operating conditions. A gear train contains more number of gears which are used to transmit power from the driving shaft to driven shaft and transmit motion in the form of chain manner. The types of gear trains are i). Simple gear train, ii). Compound gear train, iii). Reverted gear train, iv). Epicyclic gear train. Epicyclic gear train has more applications because of its designate it consist rotating gear is known as planet gear, unmovable gear is known as sun gear. The models are used to design a gear train such as Floquetlyapunor theory, new mark time integration scheme and lumped parameter dynamic model.. In this paper, the study of various models of spur gear such as micro pitting model, mesh interface model, transient elastohydrodynamic lubrication model and load distribution model. Surface interpolation model, shell model for hypoid gears and also to attain influence of design parameters on mechanical power losses and mechanical

efficiency of Spur, Helical, and Hypoid gears and also to study of vital department of planetary gear train system.

2. SPUR GEARS

Spur gears have their teeth which are straight and parallel to the axis of the wheel. They are used to transmit power between two parallel

shafts. They are simple in construction and have highest efficiency and precision rating is also high. Spur gears are used in household gadgets, motor cycle, automobiles and aircraft. It has maximum precision compared to other type of gears. Mentioned all research papers may follow common methodology as shown in the Fig 2.

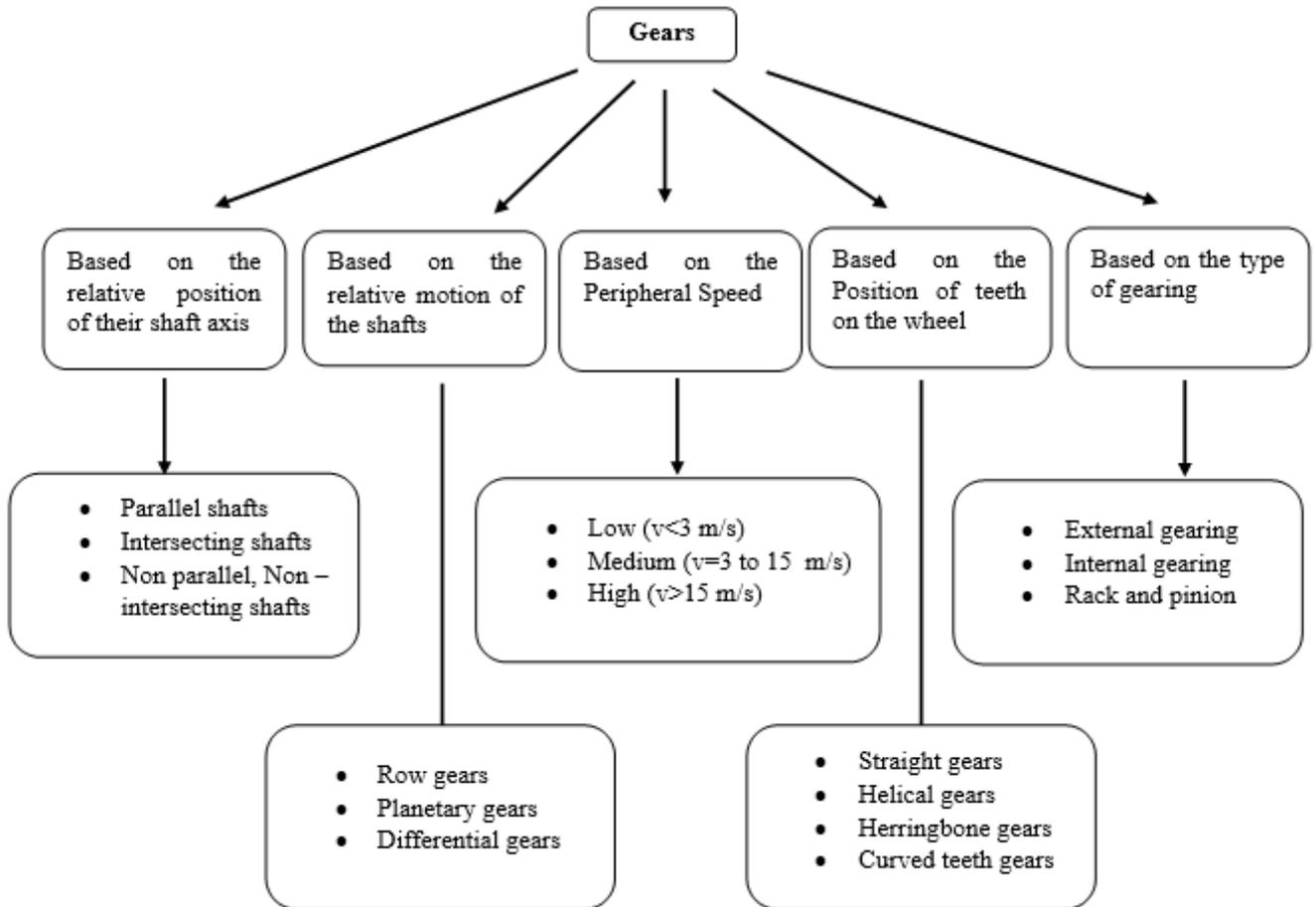


Fig.1. Classification of gears

2.1 Elastohydrodynamic lubrication model

S.Li and A Kahraman [1] has investigated “Influence of dynamic behaviour on elastohydrodynamic lubrication of spur gear”. In this study the behaviour of elastohydrodynamic lubrication of high speed spur gear contacts under dynamic condition was probed. A non-linear time varying vibratory model of spur gear is used to predict the steady state non-linear response in the form of tooth separation. In order to demonstrate the foremost influence of dynamic loading on gear

lubrication, the EHL predictions under dynamic loading condition are compared to quasi static contact loads for gear sets having smooth and rough surfaces, In this paper three mathematical models were developed such as, i). Purely torsional dynamic model of a spur gear (Fig 3) In that prediction of dynamic gear tooth contact forces, the individual dynamic tooth force is given by

$$Wd(t) = Ws(t) \left(DMF(t) \left| \left(\frac{T1}{r \ell 1} \right) \right. \right) \quad (1)$$

ii). The gear load distribution model It referred to predict $k(t)$, $e(t)$, $ws(t)$. It's associated with tooth bending, shear deformation, base rotation and contact deformation.

iii). Transient mixed EHL model

This model contained the variations of radii of curvature, sliding velocities.

$$h(x,t)=h0(t)+g0(x,t)+v(x,t)-R1(x,t)-R2(x,t) \quad (2)$$

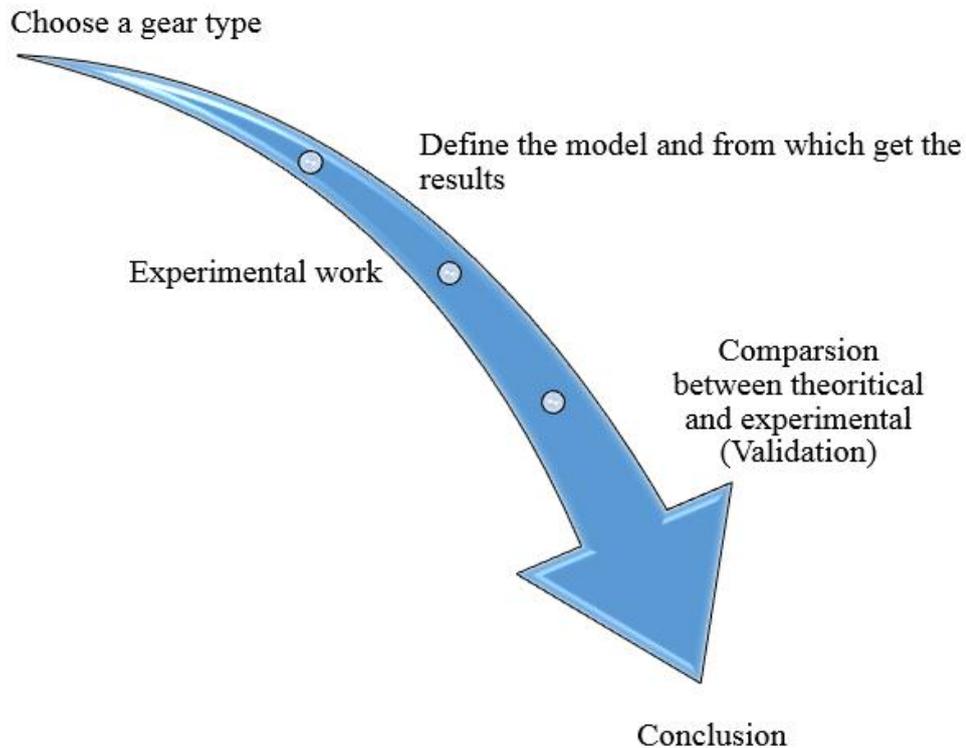


Fig 2.Common Methodology

$$W'd(t) = \int [p(x,t) dx] \quad (3)$$

The results of EHL are differ from static tooth load condition. In this model, the local contact pressure exceeds 1GPa. The load is one kind of factor which influence on $h(x,t)$, $p(x,t)$ and also surface roughness have influence on $h(x,t)$, $p(x,t)$.

S.Li and A.Kahraman [2] has presented a paper on “A spur gear mesh interface damping model based on elastohydrodynamic contact behaviour”. In this study discrete gear dynamics model was developed and the instantaneous tribological behaviour of tooth contacts was probed. This paper formulate the EHL based gear mesh viscous damping and definition of an equivalent viscous damper along the line of action is given by,

$$\xi = [(\tan \phi)^2 / \sqrt{2} km \sum_{n=1}^N Dn] \quad (4)$$

The model was developed based on the following assumptions radii of curvature was represented by pitch point expression for damping ratio was derived along the line of action. The value of gear mesh damping is proportional to the torque but inversely proportional to the rotational speed and lubricant temperature. (Dn =Gear mesh damping for nth contacting tooth pair) and they probed on “A mixed EHL model with asymmetric integrated control volume discretization” [3]. An asymmetric integrated control volume approach is employed to reduce the discretization errors. This approach is very efficient and accurate compared to other conventional approach. This method reduces the computational time and improves the efficiency of the system.

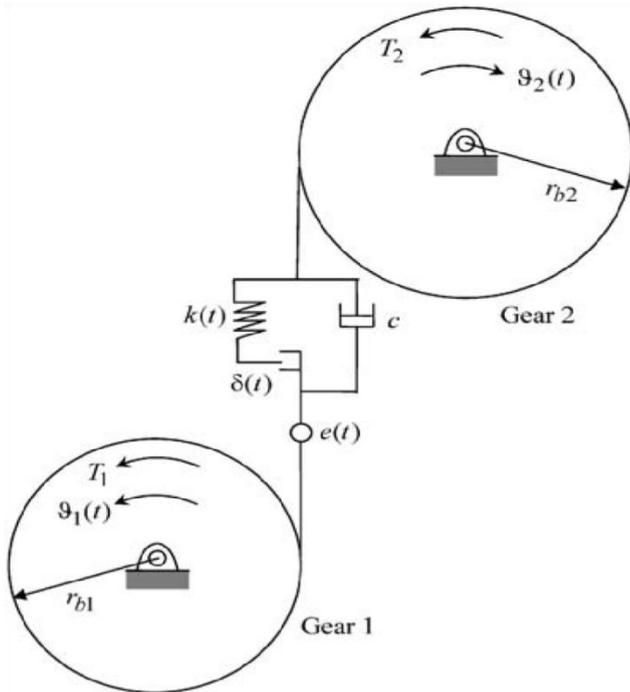


Fig.3 A purely torsional dynamic model of a spur gear pair [1]

2.2 Wind age, Spin power loss and Micro pitting model of spur gear

SathyaSeetharaman and AhmetKahraman has developed a model of wind age power loss of spur gear [4]. Wind age power loss is combination of individual gear with air or air-oil mixture. The losses due to squeezing of the same medium at the gear mesh interface. Squeezing can occur under heavy loads and insufficient at this condition, the lubrication oil film breaks down and metal to metal contact occurs. Generally power losses are divided into two categories one is load dependent (Mechanical) losses due to friction at gear mesh contact interfaces, another one load-independent (spin) power losses [5] due to lubrication method it can be occur zero torque.

Wind age and Spin power loss model is given by,

$$P_w = P_p + P_d \tag{5}$$

$$P_d = P_{d1} + P_{d2} \tag{6}$$

$$P_{d1} = P_{dci} + P_{dfi} \tag{7}$$

The lubricant property (density), Geometric parameters (module, face width), Operating condition such as temperature, rotational speed are greatest influence factors on power loss.

The module, face width is directly proportional to the power loss, torque is inversely proportional to the power loss. In spin power loss model (Fig 4) Immersion parameter is directly proportional to the power loss.

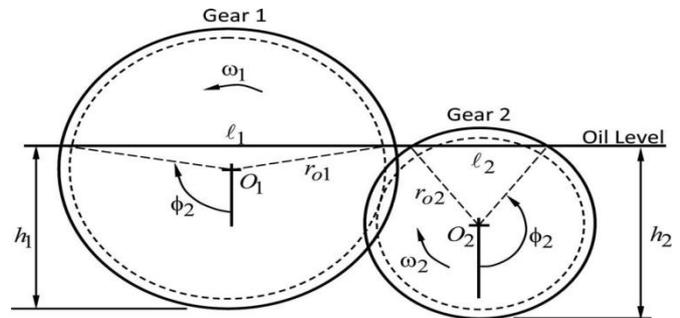


Fig 4. Definition of oil churning parameters for a gear pair immersed in oil [5].

Sheng Li and AhmetKahraman [6-9] has done a work on “ Micro pitting model for spur gear under mixed lubrication condition” The objective of the study is to discuss about micro pitting severity index (MSI) and to divine the surface normal tangential tractions, contact radii, surface velocity and normal tooth force. Pitting is a surface fatigue failure which occurs when the load on the gear tooth surface endurance strength of the material. Micro pitting severity index is ratio between micro pitted area and the entire contact area. Micro pitting formulation depends on As and the fatigue strength of the material. MIS increases between of 10 to 30 million contact cycles after that the value of MIS is decreased and they done a research work on “Micro pitting fatigue lives of lubricated point contacts: Experiment and model validation”. The aim of the experiment [7] is to find out the contribution factors on micro pitting formation. It can be mentioned that the contribution of contact pressure and rolling velocity on micro pitting formation significantly. The micro pit formation is decreased with high contact pressure and low rolling velocity. The slide to roll ratio and surface roughness amplitude is directly proportional to the micro pit formation.

2.3 Other models of spur gears

Sheng Li and AhmetKahraman [8] has probed on “Prediction of spur gear mechanical

power losses using transient elastohydrodynamic lubrication model". It can be noted that the mechanical losses are combination of sliding and rolling velocity for rough gear tooth surfaces. The instantaneous rolling and sliding velocity is calculated by means of predicated transient pressure and film thickness. The average gear mesh mechanical power loss is given by,

$$P_{\text{mesh}} = (1/N) \sum_{n=1}^N [P_{\text{mesh}}(n\Delta\psi)] \quad (8)$$

The gear module, surface roughness amplitude and operating conditions are factors influence on gear efficiency. The module, film thickness is directly proportional to the efficiency of gear system. Surface roughness is inversely proportional to the efficiency of ground and chemically polished gear 18% of loss due to asperity contact friction influence on total power loss, asperity actions are more sensitive with operating speed. Ultimately the substantial impact of rolling action on efficiency of gear drives system.

S.Li and A.Kahraman [9] has presented in his investigation paper on "A tribo-dynamic model of spur gear". The aim of the investigation is to adopt the mixed EHL model of spur gear with transverse torsional dynamic model. This model indicates two relationship and quantity the influence of operating condition, surface roughness and lubrication properties on tribo-dynamic behaviour. The surface roughness amplitude is increased with increment of bearing force due to increase of friction. The bearing force is decreased because of reduction of lubricant viscosity at higher temperature and also reduces the viscous component of F_s .

Huali Ding, AhmetKahraman [10] the objective of this paper is to study the interaction between gear surface wear and gear dynamic response. The study consists of finite element based deformable body model, simplified discrete model, and wear model and to demonstrate two way interaction between wear and dynamic behaviour. Vibration amplitude and forced frequency response influence on surface wear quantitatively and qualitatively. Smaller wear depths are divined at high speed because of increment of h_{min} and reduction of K with speed.

M.A.Hotait and A.Kahraman [11] has done

research work on "Experiment on the relationship between the dynamic transmission error and the dynamic stress factor of spur gear pairs". In this study dynamic factor on dynamic transmission error measurement from unmodified and modified spur gear is demonstrated experimentally. The intention of this paper is to show the relationship between durability and noise metrics. There is a linear relationship between DF, DTE which means to predict the linear relationship durability and noise metrics. Dynamic tooth forces and dynamic stress factors influence on vibration of gear system.

AlessioArtoni, Massimo Guiggiani, AhmetKahraman and Jonny Harianto [12] has investigated on "Optimization of gear tooth surface modification within range of torque and misalignments". The objective function is peak contact stress, loaded transmission error amplitude (to be minimized) and this study using LDP, global optimization algorithm technique. Even if only robustness to torque and misalignment has been directly integrated.

M.Kolivand and A.Kahraman [13] has done work on "General approach to locate instantaneous contact lines of gears (any type of gears) by using surface roll angle. The surface roll angle is determined by the position and normal vectors of points on one of the mating surfaces and axes of both gears. The instantaneous contact lines are attained by a novel approach. This method has several advantage compared to the conventional method. It is much faster than conventional method, avoids several computational steps, the principle curvatures. It is more accurate model because of it needs only surface and normal gear axis vectors.

Rune Pedersen, IlmarF.Santos, Iran.A.Hede has investigated on "Advantages and Drawbacks of applying periodic time-variant model analysis to spur gear dynamics". The study [14] is proposed time variant modal for examining spur gear. It can be noted that this method is accurate and ease to handle compared to time-step integration method. It gives the solution for vibration problem also the parametric resonance frequency in elastic mode does not depend on the number of Fourier components. The parametric resonance area is depends on the number of Fourier components. More number of components increases the

accuracy of the entire system.

Victor Roda – Casanova, Francisco T. Sanchez – Marin, Ignacio Gonzalez – Perez Jose L Iserte, Altonso Fuentes has done a research work [15] on “Determination of the ISO face load factor in spur gear drives by the finite element modelling of gears and shafts”. The main intension of the work is to find out kinship between the mesh alignment and the face load factor by using FEA model. That model is compared with Method C. The length of gear shaft, face width, ratio of pitch radii of gears to pitch radii of shafts are influencing factors on transmission motion done by gear system. The contribution of position of gear over shaft is not significant on the efficiency of the gear system.

Zaigang Chen, Yimin Shao has a presented a paper on “Dynamic simulation of spur gear with tooth root crack propagating along tooth width and crack depth”. The main intent of the work [16] is to study the contribution of tooth crack and vibration on mesh stiffness by using statistical indicators such as RMS and Kurtosis. The crack leads the noise so the prediction of kinshipbetwixt tooth crack and vibration is necessary one. The tool width and crack depth is independent of RMS and Kurtosis. RMS and Kurtosis is depends on the crack propagation. Crack propagation is directly proportional to the magnitude of frequency and sidebands. They investigated on “Mesh stiffness of an internal spur gear pair with ring gear rim deformation” by using Timoshenko beam theory [17]. It can be noted that type of ring support, ring thickness, number of supports and the mesh force affects the mesh stiffness of internal gear pair.

FakherCharri, WalidBaaccar, Mohamed Slim Abbas, Mohamed Haddar has investigated on “Effect of spalling or tooth breakage on gear mesh stiffness and dynamic response of a one – stage spur gear transmission” by using analytical functions[18]. Tooth breakage and Spalling are factors directly proportional to the gear mesh stiffness. The gear mesh frequency, amplitude, modulation, sidebands of the gear system which are factors evaluatethe stiffness of gear mesh.

R.G. Parker, S.M. Vijayakar, T. Imanjo has done work on “Nonlinear dynamic response of a spur gear pair: Modelling and experimental comparisons”. The aim of the study [19] is to

perusethe spur gear pair by using FEA model and contact mechanism. It can be noted that there is non-linear relationship exists between the contact loss and meshing teeth.

Yongjunshen, Shaopu Yang, Xiandong Liu has probed on “Nonlinear dynamics of a spur gear pair with time varying stiffness and backlash based on incremental harmonic balance method”. The objective is to perusethe spur system by using IBHM including

backlash, stiffness with respect to time, STE. This method is very useful to give accurate results [20]. The co-efficient ratio of gear system and excitation amplitude is the influencing factors on vital reply of gear system or managethe driving behaviour of gear system.

3. Conclusions

In this paper reviews the content of spur gear. The main intent of this paper is to understand the various models of Spur gear such as micro pitting model, mesh interface damping model, transient elastohydrodynamic lubrication model and load distribution model. Surface interpolation model, shell model for spur gears and also to attain influence of design parameters on mechanical power losses on Spur gears and also give valid information what are the factors considered while design of gears and gear train system in order to achieve desired quality

4. Future recommendations:

In this paper the different models were developed for spur, helical, hypoid gears and also gear train system in account of design parameters, lubricant properties, and operating conditions, vibration analysis. It is highly recommend that the various models will develop in account of contribution of materials properties such as fatigue strength, toughness, hardness from which to understand which properties of material, play an important role in efficiency and power loss of gear system and dynamic depportment of gear train system and also taken into contribution of composite materials because of now a days composite material play an important role in industry in order to their characteristics.

Table 1. Consolidation of Contribution factors on model

S.No	Type of gear	Gear model / Outcome	Contribution Factors on the model / Outcome
1.	SPUR GEAR SYSTEM	Windage power loss model	<ul style="list-style-type: none"> ➤ Density ➤ Face width (Direct proportional) ➤ Rotational Speed ➤ Module (Direct proportional) ➤ Temperature (Inversely proportional)
2.		Spin power model	<ul style="list-style-type: none"> ➤ Face width (Direct proportional) ➤ Temperature (Inversely proportional) ➤ Dimensionless immersion parameter (Direct proportional)
3.		Micro pitting model	<ul style="list-style-type: none"> ➤ Contact pressure ➤ Rolling velocity ➤ MIS ➤ Slide to roll ratio (Direct proportional)
4.		Efficiency of gear system	<ul style="list-style-type: none"> ➤ Module (Direct proportional) ➤ Film thickness (Direct proportional) ➤ Surface roughness (Inversely proportional) ➤ Rolling action
5.		Tribo-dynamic model	<ul style="list-style-type: none"> ➤ Operating condition ➤ Surface roughness (Direct proportional) ➤ Lubricating properties
6.		Surface wear	<ul style="list-style-type: none"> ➤ Vibration amplitude ➤ Forced frequency response
7.		Vibration of the gear system	<ul style="list-style-type: none"> ➤ Dynamic tooth forces ➤ Dynamic stress factors
8.		Periodic time-variant model	<ul style="list-style-type: none"> ➤ Parametric resonance ➤ Fourier components
9.		Transmission of motion done by gear system	<ul style="list-style-type: none"> ➤ Length of gear shaft ➤ Face width ➤ Ratio between radii of pitch of gears and radii of pitch of shaft

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