



Comprehensive Review of Gear Trains with Applications

Dharshini.S¹, Deepan Kumar.K², Dhineshababu.V³,

^{1,2,3} UG Scholar, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, Tamilnadu, India

¹gts.dharshini@gmail.com, ²deepankumark12@gmail.com, ³vrddhinesh25@gmail.com

Abstract

A mechanical effectiveness review is a necessary step in the multi-d.o.f design process. Work aims to create a system that uses a gear train which can be used to lift weights and loads. We made necessary calculations for driving load to achieve end results. Paper shows higher expectations and assumptions when designing specific components for valuable work. A think of that helped us prepare a prototype with less effort to lift required loads. The study conducted in this review paper demonstrates Gear train's optimization techniques to reduce load failures for product design enhancement and optimization.

Keywords: Micro pitting, EHL model, design parameters, Gear Train

1. Introduction:

A.Kahraman, H.Ligata, A. Singh [37] has presented a paper on “Influence of ring rim thickness on planetary gear set behavior”. The intension of the paper is to estimate the contribution of ring gear rim thickness on the rim deflection and root and hoop stresses. It can be noted that rim thickness is an important factor it should considered while designing of gear train because of it can play major role on planet load sharing of gear sets.

H. Ligata, A. Kahraman and A. Singh has conducted on “An Experimental study of the influence of Manufacturing errors on the planetary gear stresses and planet load sharing”. The intension of the experiment [4] is to study the contribution of manufacturing error such as pinhole position errors on planet load sharing and gear root stresses. It can be concluded that the contribution of manufacturing error, number of planets, torque level on planet load sharing and gear root stresses are quantatively and significantly.

A AI-Shyyab and A Kahraman [5] has developed “A nonlinear dynamic model for planetary gear sets”. This model is sufficient to study the sub

Harmonic resonance, bifurcation schemes, planet mesh phasing and planet load sharing. The model contained power flow configuration, number of planet, planet mesh phasing configuration and HBM (Harmonic balance method) formulation and they investigated [6] on nonlinear dynamic analysis of a multi-mesh gear train using multi term HBM. The HBM solution is very efficient methods compared to other methods and it is very accurate method.

M. Inalpolat, A. Kahraman has probed on “A theoretical and experimental investigation of modulation side bands of planetary gear sets”. The intension of the study [7] is to probe the modulation side bands of planetary gear sets under unequal planet load sharing inquisitively and exploratory with respect to amplitude distributions. The model includes number of planets, planet position angles and the number of teeth of the stationary gear. Whatever the planetary gear sets which will come under following categories i). Equally spaced and in phase planets, ii). Equally spaced and sequentially phased planets, iii). Unequally spaced and in phase planets, iv)

Unequally spaced sequentially phased planets, v). Unequally spaced and arbitrarily phase planets. This study indicates the following points i). The gear set is in phase and equally spaced that kind of gear sets have symmetric sidebands. ii). If the planet meshes are in phase, the harmonic amplitude will be achieved. iii). The side bands are asymmetrically distributed in case of sequential phased planetary gear sets.

2. Gear Train:

A. Kahraman and H. Ding has developed a methodology [8] to envisage surface wear of planetary gears under dynamic condition. The focus of the study is to find out wear depths at ring planet meshes and the sun planet meshes. The method contains combination of tensional dynamic model and surface wear model from that to foretell the contribution of worn surface profiles motion transmission error and contribution of dynamic tooth force on wear model. The internal gear pair wear is considered because of the wear rate of ring planet meshes smaller than the wear depth or rate of sun planet meshes in order to reduce wear cycles. The dynamic forces and harmonic amplitude contributes on surface wear in both off-resonance and resonance condition. The wear depth is high in resonance region because of increment of dynamic mesh load.

C. Yuksel and A. Kahraman has investigated on "Dynamic tooth loads of planetary gear sets having tooth profile". The objective of the paper [9] is to ascertain the contribution factors on wear model of planetary gear sets. The wear rate is dictated by Archard's wear model. This model is accurate and efficient. The wear rate is higher on the dedendum of the sun gear compared to others. The harmonic of the gear force is major factor influence on wear of planetary gear sets.

A. Kahraman, H. Ligata, K. Kienzle, D.M. Zini has done a research work on "A Kinematics and Power flow analysis methodology for automatic transmission planetary gear trains". The goal of the paper [10] is to scrutinize any type of one degree of freedom transmission planetary gear train with help of a kinematic synthesis formulation, kinematic configuration search algorithm and

power flow analysis formulation. This model is very efficient and gives the results accurate results. The components of automatic transmission PGT is as shown in Fig 1.

Zaigang Chen, Yiminshao and Daizhong Su has probed on "Dynamic simulation of planetary gear set with flexible spur ring gear". The intent of the work [11] is to find out influence factors on the dynamic behaviour of planetary gear by using Timoshenko beam theory. The flexibility of ring gear, ring thickness are the contribution factors on shape and value of the mesh stiffness of internal gear pair and driving department of planetary gear system. DTE is inversely proportional to the ring thickness.

Vijayakumar Ambarisha and Robert G. Parker has presented a paper on "Nonlinear dynamics of planetary gears using analytical and FEA model". The objective of the study [12] is to examine the dynamic behavior of spur planetary gear system by using lumped parameter and FEA model. The dynamic behavior depends on the tooth contact loss, multiple steady state solution, chaos stresses, mesh deflection, resonance condition. It can be noted that the lumped parameter model gives results accurately.

Tristan M. Ericson, Robert G. Parker has investigated on "Planetary gear model vibration experiments and correlation against lumped parameter and finite element models". The aim of the work [13] is to signalize the vital department of planetary gear in terms of rotational, irrotational vibrations, natural frequencies, mode shapes by using lumped parameter model and FEA modal. The higher frequency modes are greatest influence factor on the tooth mesh deflection. The driving behaviour modal including highest planet bearing stiffness and radial stiffness gives accurate results than the modal contained PBSE because isotropic planet bearing stiffness assumption gives more error for entire gear system. The custom designed is obtained in 17th natural frequency in the case of lumped parameter modal and 9th natural frequency in case of FEA modal. The percentage of error is tabulated in table 1 and 2.

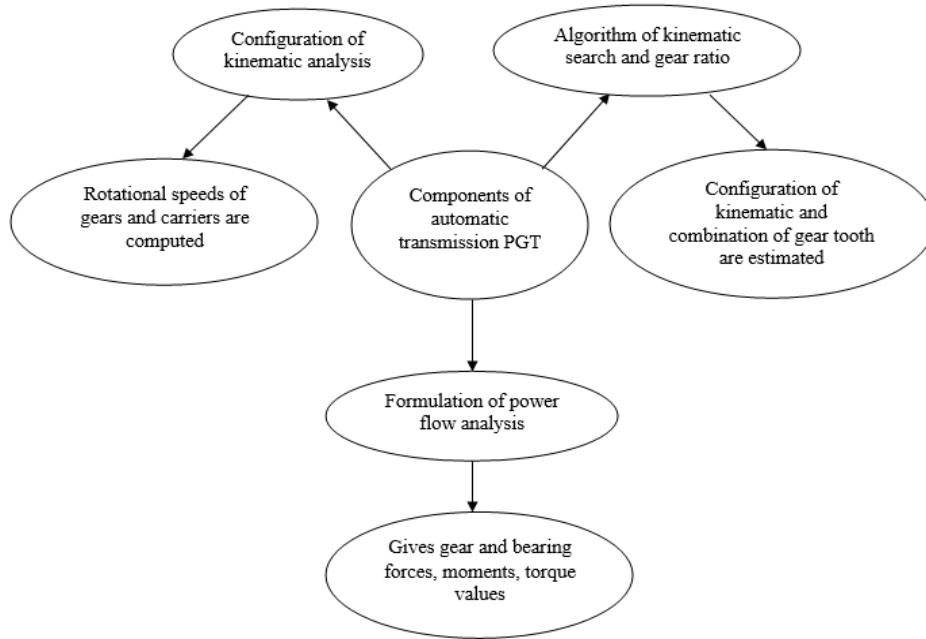


Fig 1. Components of automatic transmission PGT

Table 1 Errors percentage in Lumped parameter model

S.NO	Model	Number of Natural frequency	Percentage of (%) error
1.	Lumped parameter model	13 th Natural frequency	Within 5% error
2		16 th Natural frequency	Within 10% error
3.		Remaining all Natural frequency	Within 13% error

Table 2 Errors percentage in FEA model

S.NO	Model	Number of Natural frequency	Percentage of (%) error
1.	FEA model	5 th Natural frequency	Within 5% error
2		7 th Natural frequency	Within 10% error
3.		9 th Natural frequency	Within 4% error
4.		Remaining all Natural frequency	Within 20% error

Zaigang Chen, Yimin Shao has done a work on “Dynamic simulation of planetary gear with root crack in ring gear”. The intent of the

research work [14] is to examine the dynamic response of planetary gear by using potential energy principle. It can be noted that the

internal gear tooth root crack is inversely proportional to the mesh stiffness. The internal gear tooth root crack is the greatest influencing factor on dynamics response of planetary system. It changes the frequency system and produces more sidebands and proportional to the amplitudes of the gear system.

X. Gu and P. Velex [15] has developed "A model to study influence of planet position errors in planetary gears". The objective of the study is to peruse planetary in terms of errors and deflection by using classic lumped parameter model. The planet deflections and errors are contribution factors on expeditious gear geometry. The mesh stiffness is directly proportional to the contact length. The expeditious gear geometry is predicted in account of actual pressure angle, contact ratio, position of base planes, meshing areas.

Woohyung Kim, JiYeong Lee, Jintai Chung has probed on "Dynamics analysis for a planetary gear with time varying pressure angles and contact ratios". The objective of the paper [16] is to peruse the dynamic behaviour of planetary gear by using newmark time integration scheme. The model is proposed with change of pressure angles and contact ratio with respect to time. The amplitude of system inversely proportional to the bearing stiffness. This model gives highest radial displacements. Zhonghong Bu, Geng Liu, Liyan Wu [17] has probed on "Modal analyses of herringbone planetary gear train with journal bearing". The objective of the study is to examine the herring bone planetary gear train by using analytical model including vibration studies also. The vibration mode contained rotational and axial, translational, planet, rotational and axial ring mode, translational ring mode. The mode shapes of TM are greatest influence factor on driving behaviour of journal bearing. The model strain and kinetic energy helps to scrutinize frequency without deviation.

X. Gu and P. Velex has done a research work on "The dynamic simulation of eccentricity errors in planetary gears". The intension of the study [18] is to examine the errors relevant eccentricity of planetary gear system by

lumped parameter model. Errors affect the dynamic behaviour, transmission of motion and load sharing. Those kinds of errors are reduced by floating members. Centrifugal force is created by rotating carrier. It reduces sun gear-planet contact ratio and noise of the system in terms of vibration.

3. Other models of gear train

Avinash Sign has presented a paper [19] on "Load sharing behaviour in epicyclic gears: physical explanation and generalized formulation". The planet to planet load sharing is evaluated by closed form non dimensional equations included positional errors. The floating system eliminates one portion of error. The remaining portions are eliminated by elastic deformation. The number of planets directly proportional to the position error. The quantity of float of system does not affect the load sharing significantly.

S. Theodossiades and S. Natsiavas has probed on "Nonlinear dynamics of gear pair systems with periodic stiffness and backlash" by using response diagrams [20]. It can be noted that backlash, mesh stiffness are strongest contribution factors on driving department of gear system. Mesh stiffness is directly proportional to the dynamic response with nonzero backlash condition. Harmonic forcing is influence factor on amplitude type and periodic response. Damping is directly proportional to the driving reply and inversely proportional to the amplitude of the system

Haidong Yu, Peter Eberhard, Yong Zhao, Haowang has probed on "Sharing behaviour of load transmission on gear pair systems actuated by parallel arrangements of multiple pinions". The objective of the study [21] is to analyse the gear pair system by multiple pinions which are arranged parallels. The ratio of gear to load sharing index meshing frequency, bearing stiffness pinions, mounting locations of pinions, gear configuration coefficients are the factors on the load transmission behaviour of gear pair system. These are predicted by Floquetlyapunor theory and lumped parameter dynamic model.

Table 3. Consolidation of Contribution factors on model

S.No	Type of gear	Gear model / Outcome	Contribution Factors on the model / Outcome
1.	Planetary Gear Train	Dynamic behaviour	<ul style="list-style-type: none"> ➤ Rim thickness (Inversely proportional to DTE) ➤ Number of planets ➤ Torque on planet load sharing ➤ Root stresses ➤ Mesh stiffness ➤ Tooth root crack (Inversely proportional to mesh stiffness) ➤ Actual pressure angle ➤ Contact ratio ➤ Position of base planes ➤ Meshing areas ➤ Amplitude of the system (Inversely proportional to bearing stiffness) ➤ Mode shapes of TM ➤ Backlash ➤ Harmonic forcing ➤ Damping ➤ Ratio of gear to load sharing index ➤ Meshing Frequency ➤ Bearing stiffness ➤ Mounting locations of pinions ➤ Gear configuration coefficient
2.		Surface wear	<ul style="list-style-type: none"> ➤ Dynamic forces (Direct proportional) ➤ Harmonic amplitude

4. Conclusions

In this paper, the rim thickness is important factor, it has more contribution on efficiency of gear train system.

1. Harmonic balance method is very efficient method and accurate method compared to traditional methods.
2. The archard's wear model is used to foretell the wear rate of gear train. This method is very efficient and accurate.
3. The tooth contact loss, multiple steady state solution, chaos stresses, mesh

deflection, resonance condition are contribution factors on dynamic behavior of gear train.

4. The floating members are used in gear train because which are used to disqualify the errors of gear train system.
5. Floquetlyapunor theory, new mark time integration scheme and lumped parameter dynamic model are used in gear train to peruse the dynamic department of planetary gear train system.

6. Backlash, mesh stiffness and damping are contribution factors on driving behavior of planetary gear train system

5. 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 department 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.

References

- [1]. H. Xu, A. Kahraman, N.E. Anderson, D.G. Maddock. "Prediction of Mechanical efficiency of parallel-Axis gear pairs". *Journal of Mechanical Design* JANUARY 2007, Vol. 129 DOI: 10.1115/1.2359478.
- [2]. J. Hong, D. Talbot, A. Kahraman. "Load distribution analysis of clearance-fit spline joints using finite elements". *Mechanism and Machine Theory* 74 (2014) 42–57. <http://dx.doi.org/10.1016/j.mechmachtheory.2013.11.007>.
- [3]. A. Kahraman, H. Ligata, A. Singh. "Influence of ring rim thickness on planetary gear set behavior". *Journal of Mechanical Design* FEBRUARY 2010, Vol. 132 / 021002 DOI: 10.1115/1.4000699.
- [4]. H. Ligata, A. Kahraman and A. Singh. "An Experimental study of the influence of Manufacturing errors on the planetary gear stresses and planet load sharing". *Journal of Mechanical Design*. APRIL 2008, Vol. 130 / 041701. DOI: 10.1115/1.2885194.
- [5]. A. AI-Shyyab and A. Kahraman. "A nonlinear dynamic model for planetary gear sets" *Proc. IMechE Vol. 221 Part K: J. Multi-body Dynamics JMBD92* © IMechE 2007 DOI: 10.1243/14644193JMBD92.
- [6]. A. AI-Shyyab and A. Kahraman. "Non-linear dynamic analysis of a multi-mesh gear train using multi-term harmonic balance method: period-one motions". *Journal of Sound and Vibration* 284 (2005) 151–172. DOI:10.1016/j.jsv.2004.06.010.
- [7]. M. Inalpolat, A. Kahraman. "A theoretical and experimental investigation of modulation side bands of planetary gear sets". *Journal of Sound and Vibration* 323 (2009) 677–696. DOI: 10.1016/j.jsv.2009.01.004.
- [8]. A. Kahraman and H. Ding. "A Methodology to Predict Surface Wear of Planetary Gears under Dynamic Conditions". *Mechanics Based Design of Structures and Machines: An International Journal*, 38:4, 493-515, DOI:10.1080/15397734.2010.501312.
- [9]. C. Yuksel and A. Kahraman. "Dynamic tooth loads of planetary gear sets having tooth profile". *Mechanism and Machine Theory* 39 (2004) 695–715. DOI:10.1016/j.mechmachtheory.2004.03.001.
- [10]. A. Kahraman, H. Ligata, K. Kienzle, D.M. Zini. "A Kinematics and Power flow analysis methodology for automatic transmission planetary gear trains". *Journal of Vibration and Acoustics* JULY 2004, Vol. 126 DOI: 10.1115/1.1760561#.
- [11]. Zaigang Chen, Yimin Shao and Daizhong Su "Dynamic simulation of planetary gear set with flexible spur ring gear" *Journal of Sound and Vibration* 332 (2013) 7191–7204.
- [12]. Vijayakumar Ambarisha and Robert G. Parker has a presented a paper on "Nonlinear dynamics of planetary gears using analytical and FEA model". *Journal of Sound and Vibration* 302 (2007) 577–595.
- [13]. Tristan M. Ericson, Robert G. Parker. "Planetary gear model vibration experiments and correlation against lumped parameter and finite element models". *Journal of Sound and Vibration* 332 (2013) 2350–2375.
- [14]. Zaigang Chen, Yimin Shao. "Dynamic simulation of planetary gear with root crack

in ring gear". Engineering Failure Analysis 31 (2013) 8–18.

[15]. X. Gu and P. Velex, "A model to study influence of planet position errors in planetary gears". Journal of Sound and Vibration 331 (2012) 4554–4574.

[16]. Woohyung Kim, JiYeong Lee, Jintai Chung. "Dynamics analysis for a planetary gear with time varying pressure angles and contact ratios". Journal of Sound and Vibration 331 (2012) 883–901.

[17]. Zhonghong Bu, Geng Liu, Liyan Wu. "Modal analyses of herringbone planetary gear train with journal bearing" Mechanism and Machine Theory 54 (2012) 99–115.

[18]. X. Gu and P. Velex "The dynamic simulation of eccentricity errors in planetary gears". Mechanism and Machine Theory 61 (2013) 14–29.

[19]. Avinash Sign. "Load sharing behaviour in epicyclic gears: physical explanation and generalized formulation". Mechanism and Machine Theory 45 (2010) 511-530.

[20]. S. Theodossiades and S. Natsiavas. "Nonlinear dynamics of gear pair systems with periodic stiffness and backlash" Journal of Sound and vibration(2000) 229(2), 287310 Article No. jsvi.1999.2490.

[21]. Haidong Yu, Peter Eberhard, Yong Zhao, Haowang. "Sharing behaviour of load transmission on gear pair systems actuated by parallel arrangements of multiple pinions". Mechanism and Machine Theory 65 (2013) 58–70.