

How to Design a Successful Online Course

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Performance Based Gear Metrology Kinematic Transmission Error Computation And Diagnosis

Vincenzo Vullo

A decorative graphic element consisting of a light blue horizontal bar with a rounded right end, and a red circular gradient shape partially visible behind it.

Performance Based Gear Metrology Kinematic Transmission Error Computation And Diagnosis:

Performance-Based Gear Metrology William D. Mark, 2012-11-09 A mathematically rigorous explanation of how manufacturing deviations and damage on the working surfaces of gear teeth cause transmission error contributions to vibration excitations. Some gear tooth working surface manufacturing deviations of significant amplitude cause negligible vibration excitation and noise yet others of minuscule amplitude are a source of significant vibration excitation and noise. Presently available computer numerically controlled dedicated gear metrology equipment can measure such error patterns on a gear in a few hours in sufficient detail to enable accurate computation and diagnosis of the resultant transmission error vibration excitation. How to efficiently measure such working surface deviations compute from these measurements the resultant transmission error vibration excitation and diagnose the manufacturing source of the deviations is the subject of this book. Use of the technology in this book will allow quality spot checks to be made on gears being manufactured in a production run to avoid undesirable vibration or noise excitation by the manufactured gears. Furthermore those working in academia and industry needing a full mathematical understanding of the relationships between tooth working surface deviations and the vibration excitations caused by these deviations will find the book indispensable for applications pertaining to both gear quality and gear health monitoring. Key features: Provides a very efficient method for measuring parallel axis helical or spur gears in sufficient detail to enable accurate computation of transmission error contributions from working surface deviations and algorithms required to carry out these computations including examples. Provides algorithms for computing the working surface deviations causing any user identified tone such as ghost tones or sidebands of the tooth meshing harmonics enabling diagnosis of their manufacturing causes including examples. Provides explanations of all harmonics observed in gear caused vibration and noise spectra. Enables generation of three dimensional displays and detailed numerical descriptions of all measured and computed working surface deviations including examples.

Dudley's Handbook of Practical Gear Design and Manufacture Stephen P. Radzevich, 2016-09-15 Dudley's Handbook of Practical Gear Design Manufacture Third Edition is the definitive reference work for gear design production inspection and application. This fully updated edition provides practical methods of gear design and gear manufacturing methods for high medium and low volume production. Comprehensive tables and references are included in the text and in its extensive appendices providing an invaluable source information for all those involved in the field of gear technology.

Gear Cutting Tools Stephen P. Radzevich, 2017-10-16 Gear Cutting Tools Fundamentals of Design and Computation Second Edition presents the DG K based method of surface generation a practical mathematical method for designing gear cutting tools with optimal parameters. The text addresses gear cutting tool evolution and proceeds to scientific classification for all types of gear machining meshes before discussing optimal cutting tool designs. Designs currently used and those being planned are covered and the approach allows for development of scientific predictions and optimal designs. Solutions appear in analytical form and or graphical

form with a wealth of new figures added and new appendices offer additional data for readers

Advanced Mathematical and Computational Tools in Metrology and Testing VIII Franco Pavese, 2009 The main theme of the AMCTM 2008 conference reinforced by the establishment of IMEKO TC21 was to provide a central opportunity for the metrology and testing community worldwide to engage with applied mathematicians statisticians and software engineers working in the relevant fields This review volume consists of reviewed papers prepared on the basis of the oral and poster presentations of the Conference participants It covers all the general matters of advanced statistical modeling e g uncertainty evaluation experimental design optimization data analysis and applications multiple measurands correlation etc metrology software e g engineering aspects requirements or specification risk assessment software development software examination software tools for data analysis visualization experiment control best practice standards etc numerical methods e g numerical data analysis numerical simulations inverse problems uncertainty evaluation of numerical algorithms applications etc and data fusion techniques and design and analysis of inter laboratory comparisons

Laser Metrology and Machine Performance IV Vic Chiles, Des Jenkinson, 1999 This collection of papers from the Fourth International Conference on Laser Metrology and Machine Performance reflects the growing emphasis on engineering performance of surfaces There is also coverage of research efforts involving thermal errors on machine tools Developments in ISO standards also continue to be highlighted The papers come from acknowledged experts working in industry research establishments and academia in many countries and cover the following topical areas calibration systems condition monitoring machine tool standards thermal errors of machine tools hexapod calibration gear measurement surface measurements machine tool errors machine tool measurement systems and machine tool performance

A Transmission-error-based Gear Dynamic Model Nina Sainte-Marie, 2016 Noise measurements have shown that helicopters main gearboxes highly contribute to the overall cabin noise Gear mesh vibrations propagate through the shafts to the rolling element bearings and the casing which becomes a source of radiated noise The latter is characterized by high amplitude tones emerging from broadband noise whose frequencies lie in the range of maximum human ear sensitivity In the context of continuous improvement in the acoustic comfort of helicopter passengers it is therefore necessary to analyse and optimize gearbox vibrations in order to reduce casing noise radiations The research work presented in this memoir is focused on the development of a numerical model dedicated to the prediction of gear system dynamic behaviour comprising several gear stages and different types of gears This model relies on classic beam and lumped parameter elements along with specific two node gear elements for both cylindrical spur helical and spiral bevel gears The equations of motion are developed based on time varying functions representative of mesh excitations which comprise a mesh stiffness functions b quasi static transmission error under load and c kinematic or no load transmission error A number of comparisons with benchmark numerical and experimental results from the literature are presented which demonstrate that the proposed approach is sound as far as single stage systems with

spur helical or spiral bevel gears are considered. Validations are then extended to double stage gears and here again it is confirmed that the proposed transmission error based formulation is accurate and can account for tooth shape modifications. In the second part of the memoir several examples of application are presented and commented upon. First the combined influence of tooth pitch errors and load on the dynamic behaviour of gear transmissions is tackled. An extended three dimensional model and a reduced torsional version are then confronted in order to investigate the dependency between dynamic transmission errors and mesh force root stress dynamic factors. Further investigations on bearing dynamic response in two stage spur gear systems are conducted and the particular contributions of profile modifications are analysed. Finally a system combining a cylindrical gear and a spiral bevel gear is considered and particular attention is paid to the dynamic couplings between the various meshes and their influence on bearing dynamic responses. *A Study on the Relationship Between the Dynamic Factor and the Dynamic Transmission Error of Spur Gear Pairs* Venkata Krishna Tamminana, 2005

Abstract Power Transmission systems are widely used in automotive and aerospace industries. These systems are often operated under relatively high rotational speeds and hence their dynamic behavior especially its impact on the gears becomes a relevant issue. Dynamic behavior of gear systems is important for two main reasons: durability and noise. In this study two different dynamic models: a finite elements based deformable body model and a simplified discrete model are developed to predict dynamic behavior of spur gear pairs. The deformable body model will have the ability to predict both DTE and DF based on mesh and tooth forces as well as dynamic gear tooth bending stresses. The discrete model will rely on the deformable body model for computation of gear mesh parameters under quasi static conditions and will predict both DTE and DF based on mesh and tooth forces. Dynamic transmission error (DTE) and dynamic factors (DF) defined based on the gear mesh loads, tooth loads and bending stresses are computed for a number of unmodified and modified spur gears within a wide range of rotational speed for different involute contact ratios and torques. Both models are validated by comparing their DTE predictions with experimental data obtained from a set of tests using spur gear having unmodified and modified tooth profiles. The predicted DF and DTE values are related to each other through simplified formulas. Impact of nonlinear behavior such as tooth separations and jump discontinuities on DF is also quantified. **Loaded Transmission Error**

Measurement System for Spur and Helical Gears Zachary Harrison Wright, 2008 **Abstract** The majority of loaded static transmission error test stands developed in the past had little success generating accurate results versus analytical predictions for parallel axis gearing. Design flaws historically caused issues with speed and torque control ultimately leading to erroneous results. Fortunately some of these issues were corrected through the years most recently by Schmitkors. 1 for loaded transmission error testing of bevel gears sets. The original goal of this thesis was to translate those successes into a test rig for parallel axis gearing that can measure static transmission error and shaft deflections to take a look at transmission error shuttling and friction force excitations. However due to difficulties in achieving a good comparison

between experimental results and analytical predictions the goal was shifted towards simply assessing the performance of the new test stand By using virtually the same control setup and measurement setup as the loaded bevel gear static transmission error test stand the new test stand generated static transmission error results for both spur and helical gears at various torque levels Those results were compared to analytical prediction software codes WindowsLDP RomaxDesigner and Helical3D using optimal and measured micro geometry topographies The static transmission error results compared well at low torque values but deviated from the predicted trends at higher torque values Ultimately lessons learned from this test setup will be reflected in future experimental work in order to better assess the accuracy of prediction tools

International Gear Conference 2014: 26th-28th August 2014, Lyon Philippe Velez, 2014-09-18 This book presents papers from the International Gear Conference 2014 held in Lyon 26th 28th August 2014 Mechanical transmission components such as gears rolling element bearings CVTs belts and chains are present in every industrial sector and over recent years increasing competitive pressure and environmental concerns have provided an impetus for cleaner more efficient and quieter units Moreover the emergence of relatively new applications such as wind turbines hybrid transmissions and jet engines has led to even more severe constraints The main objective of this conference is to provide a forum for the most recent advances addressing the challenges in modern mechanical transmissions The conference proceedings address all aspects of gear and power transmission technology and range of applications aerospace automotive wind turbine and others including topical issues such as power losses and efficiency gear vibrations and noise lubrication contact failures tribo dynamics and nano transmissions A truly international contribution with more than 120 papers from all over the world A judicious balance between fundamental research and industrial concerns Participation of the most respected international experts in the field of gearing A wide range of applications in terms of size power speed and industrial sector An Experimental Investigation of the Effect of Spacing Errors on the Loaded Transmission Error of Spur Gear Pairs Brian Anichowski (Jr.), 2017 This paper complements recent investigations Handschuh et al 2014 Talbot et al 2016 of the influences of tooth indexing errors on dynamic factors of spur gears by presenting data on changes to the dynamic transmission error An experimental study is performed using an accelerometer based dynamic transmission error measurement system incorporated into a high speed gear tester to establish baseline dynamic behavior of gears having negligible indexing errors and to characterize changes to this baseline due to application of tightly controlled intentional indexing errors Spur gears having different forms of indexing errors are paired with a gear having negligible indexing error Dynamic transmission error of gear pairs under these error conditions is measured and examined in both time and frequency domains to quantify the transient effects induced by these indexing errors These measurements are then compared against the baseline no error condition as a means to quantify the dynamic vibratory behavior induced due to the tooth indexing errors These comparisons between measurements indicate clearly that the baseline dynamic response dominated by well defined resonance peaks and

mesh harmonics are complemented by non mesh orders of transmission error due the transient behavior induced by indexing errors In addition the tooth or teeth having indexing error imparts transient effects which dominate the vibratory response of the system for significantly more mesh cycles than the teeth having errors are in contact For this reason along with the results presented in Talbot et al 2016 it was concluded that spur gears containing indexing errors exhibit significant deviations from nominal behavior at both a system and time domain level Theory and Practice of Gearing and

Transmissions Veniamin Goldfarb,Natalya Barmina,2015-08-26 This book brings together papers from all spheres of mechanical engineering related to gears and transmissions from fundamentals to advanced applications from academic results in numerical and experimental research to new approaches to gear design and aspects of their optimization synthesis and to the latest developments in manufacturing Furthermore this volume honours the work of Faydor L Litvin on the 100th anniversary of this birth He is acknowledged as the founder of the modern theory of gearing An exhaustive list of his contributions and achievements and a biography are included **Gears** Vincenzo Vullo,2020-01-24 The book explores the geometric and kinematic design of the various types of gears most commonly used in practical applications also considering the problems concerning their cutting processes The cylindrical spur and helical gears are first considered determining their main geometric quantities in the light of interference and undercut problems as well as the related kinematic parameters Particular attention is paid to the profile shift of these types of gears either generated by rack type cutter or by pinion rack cutter Among other things profile shifted toothing allows to obtain teeth shapes capable of greater strength and more balanced specific sliding as well as to reduce the number of teeth below the minimum one to avoid the operating interference or undercut These very important aspects of geometric kinematic design of cylindrical spur and helical gears are then generalized and extended to the other examined types of gears most commonly used in practical applications such as straight bevel gears crossed helical gears worm gears spiral bevel and hypoid gears Finally ordinary gear trains planetary gear trains and face gear drives are discussed Includes fully developed exercises to draw the reader s attention to the problems that are of interest to the designer as well as to clarify the calculation procedure Topics are addressed from a theoretical standpoint but in such a way as not to lose sight of the physical phenomena that characterize the various types of gears which are examined The analytical and numerical solutions are formulated so as to be of interest not only to academics but also to designers who deal with actual engineering problems concerning the gears **System-level Identification and Analysis**

of Gear Dynamics Shengli Zhang,2017 This study presents an effort in system level identification and gear dynamics analysis The mechanical system usually includes several parts with different mechanisms to achieve a particular job To simulate the motion of the parts evaluate the performance and analyze the vibration of the system a system level modeling is needed However the modeling is challenging because of unknown parameters nonlinearities and uncertainties System identification is one of the key techniques to obtain a reliable dynamic model by appropriately choosing the mathematical

model identifying the unknowns and reducing the uncertainties This study illustrates approaches and procedures in building system level model for an electric impact wrench Electric impact wrench whose operation involves dynamic events occurring at vastly different time scales is an important tool used in manufacturing and maintenance services where high torque is required A first principle based system level model is built by incorporating the dynamics of gear transmission spindle and impacting components The nonlinear impact and kinematic constraints are explicitly analyzed and systematic parametric identification is performed based on a multi objective optimization approach i e archived multi objective simulated annealing The predictions from the model with system identification correlate well with the experimental results In the system level modeling it is found that gear transmission is one of the most popular and important sub system whose dynamics and health conditions affect the system performance significantly Therefore this study also presents the effort in the gear dynamics analysis and fault diagnosis It is well known that the nonlinear characteristics of the gearbox are mainly induced by time varying mesh stiffness and backlash To solve this nonlinear system numeric method is usually employed whose time step has to be carefully controlled and the accuracy suffers from cumulative errors To overcome the limitations of the numeric method an approach integrating Floquet theory with harmonic balance method is proposed to analytically analyze the dynamics of the gearbox that subjects to parameter excitation and backlash nonlinearity This approach can not only solve the steady state system response as traditional harmonic balance method but also the transient response of the system Case study verifies the accuracy of the proposed approach and its efficiency in calculating the frequency response of the system The proposed method also accurately predicts the nonlinear jump of the gearbox In the gear fault diagnosis a fault signature enhancement method i e angle frequency domain synchronous averaging is developed This method is capable of highlighting the fault related features from the nonstationary and noisy vibration signal Rather than being averaged in time domain as traditional method the vibration signal is averaged in angle frequency domain after being resampled from time domain into angle domain and analyzed by the joint angle frequency technique so as to solve the phase shift problem The enhanced results are then analyzed through feature extraction algorithms i e Kernel Principal Component Analysis Multilinear Principal Component Analysis and Locally Linear Embedding to extract the most distinct features for fault classification and identification Experimental study demonstrates that the proposed method significantly enhances the fault related features and improves the identification rate of support vector machine in identifying multi gear faults Gears Vincenzo

Vullo,2020-02-21 This book explores the geometric and kinematic design of the various types of gears most commonly used in practical applications also considering the problems concerning their cutting processes The cylindrical spur and helical gears are first considered determining their main geometric quantities in the light of interference and undercut problems as well as the related kinematic parameters Particular attention is paid to the profile shift of these types of gears either generated by rack type cutter or by pinion rack cutter Among other things profile shifted toothing allows to obtain teeth shapes capable of

greater strength and more balanced specific sliding as well as to reduce the number of teeth below the minimum one to avoid the operating interference or undercut These very important aspects of geometric kinematic design of cylindrical spur and helical gears are then generalized and extended to the other examined types of gears most commonly used in practical applications such as straight bevel gears crossed helical gears worm gears spiral bevel and hypoid gears Finally ordinary gear trains planetary gear trains and face gear drives are discussed This is the most advanced reference guide to the state of the art in gear engineering Topics are addressed from a theoretical standpoint but in such a way as not to lose sight of the physical phenomena that characterize the various types of gears which are examined The analytical and numerical solutions are formulated so as to be of interest not only to academics but also to designers who deal with actual engineering problems concerning the gears

An Experimental Investigation Into the Influence of Various Errors on the Transmission Error and Root Stresses of Spur Gears Mark Robert Milliren, 2011 Abstract In this study an experimental investigation is performed to investigate the impact of various gear errors on transmission error and root fillet stresses A test set up is devised to operate a pair of spur gears under loaded low speed conditions Two measurement systems one an optical encoder based transmission error measurement system and the other a multi channel strain measurement system are developed and implemented with the test set up A set of test gears having various types and tightly controlled magnitudes of manufacturing errors are designed and procured These errors include indexing errors of different tooth sequences pitch line run out errors and lead wobble errors An extensive test matrix is executed to quantify the impact of these errors on the loaded static transmission error and the root stresses of the spur gears At the end the same test conditions are simulated by using a recent feature of gear analysis model LDP to assess the accuracy of its predictions

Development of a Digital Data Acquisition and Analysis System for the Measurement of Dynamic Transmission Error of Spur and Helical Gear Pairs Michael Heskamp, 2007 Abstract In this thesis digital data acquisition software is developed and implemented with an accelerometer based instrumentation for the measurement of motion transmission errors of parallel axis gear pairs operating under dynamic conditions This system digitizes the acceleration signals from diametrically opposed tangential transducers mounted on each gear wheel to determine angular accelerations of both the mating gears These signals are combined and integrated twice to obtain the dynamic transmission error DTE along the line of action The measured DTE is processed under constant speed or sweep up and sweep down conditions to determine the harmonic content of the steady state vibration response as well as transient response in the form of waterfall plots The DTE values obtained by using the digital method are compared to those obtained from an analog system to show a good correlation The digital data acquisition and analysis system is then used to measure the DTE of a number of example spur and helical gears having different modifications and contact ratios At the end capabilities and limitations of this approach for measuring DTE are discussed

Gear Metrology C. A. Scoles, R. Kirk, 1969

A Theoretical and Experimental Study of Static and Dynamic Transmission Error for Spur and Helical Gears

with Various Modifications and Contact Ratios James M. Graber, 1994 *Theory of Gearing* Stephen P. Radzevich, 2022-11-29 Updated throughout for the third edition *Theory of Gearing Kinematics Geometry and Synthesis* is an essential resource for engineers in the field of gearing Detailing gear design production inspection and application the book covers cutting edge gear types to enable the reader to fully keep track of modern gear developments Demonstrating the rigorous scientific theory behind optimal gear design manufacture and performance a key focus of the new edition is on aiding engineers in designing low noise transmissions in smaller sizes improving fuel consumption and reducing emissions Chapters included will discuss key features of Split Power Transmission Systems SPTS with equal almost equal power share and Uniform Rotary Motion Entirely new chapters for the third edition include Parallel Axes involute gearing of specific design and gear and Novikov Conformal and High Conformal gearing The book will be of interest to engineers and researchers in the gearing industry It will also have relevance to those working in tribology metallurgy and materials processing alongside engineers working in precision manufacturing **Comparisons Between Measured and Predicted Transmission Error of Unloaded Spur Gears** Peter Damien Biggert, 1990

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