PREFACE

This book is a compendium of the primary author's fifty years of experience in cam design and research. For thirty years while teaching and doing original research at WPI, he and his students explored the intricacies of cam design and manufacturing and published many papers on the subject. For fifteen years, he served as a consultant to the Gillette Company, helping them improve their cam design procedures based on his research. Their factory full of cam-driven machinery, to which he had full access, was his "practical laboratory" to test and prove or disprove his theories on how to design and manufacture a better cam.

Cam-follower systems are an extremely important and ubiquitous component in all kinds of machinery. It is difficult to find examples of machinery that do not use one or more cams in their design. Cams are the first choice of many designers for motion control where high precision, repeatability, and long life are required. All automotive engines depend on cams for their proper valve function. Most automated production machinery uses cams extensively.

The design and manufacture of cams has changed dramatically in recent years. The development and proliferation of computers in engineering design and of numerical control in manufacturing have completely changed the process of cam design and manufacturing, and very much for the better. Until about the late 1960s cams were designed only by manual graphical layout techniques, manufactured in low quantities by manually controlled machining methods and in high quantities by analog duplication of a hand-dressed master cam. The subtleties of the effects of higher derivatives of the cam's chosen mathematical function were often ignored, due either to ignorance of their importance, or the inability to accurately determine their effects given the lack of computational facilities available at the time.

Currently, it is virtually universal and also very economical to use computer-aided engineering and design techniques to create cam geometry, including proper consideration of the effects of higher derivatives, and also to make the cam with high precision using continuous numerically controlled milling, grinding, or electrical discharge machining (EDM) equipment. A significant number of fundamental research results on the subject of cam design and manufacture have been published in recent years. This book is intended to provide a definitive reference for the design and manufacturing of cam-follower systems by bringing up-to-date cam design technology and cam research together between a single set of covers for the benefit of the design and manufacturing engineering community.

The book takes the subject from an introductory level through advanced topics needed to properly design, model, analyze, specify, and manufacture cam-follower systems. Beginning with a description of "how not to design a cam" in order to point out pitfalls that may not be obvious to the beginner, the proper way to design a cam for multiple and single-dwell situations is developed in detail. All the acceptable (and some unacceptable) classical cam functions are described and their mathematics defined for the common double-dwell application. Polynomial functions are introduced and used for both double- and single-dwell examples. Problems with polynomial cams are defined in detail and ways to design around these problems are discussed. Spline functions are introduced as a class of cam motion functions that can solve the most difficult cam design problems. Many examples are developed to show how splines, especially B-splines, can solve otherwise intractable cam design problems.

The issues of cam pressure angle and radius of curvature are fully addressed for various types of cams and followers: radial, barrel, globoidal, translating, and oscillating, roller and flat-faced. The dynamics of the cam-follower system are introduced along with techniques for modeling the follower system as lumped parameters. Both the inverse dynamic (kinetostatic) and forward dynamic solutions are developed for a multiplicity of mathematical models of various degrees of freedom. The extensive literature on these topics is referenced in the bibliography. Residual vibrations in the follower train are addressed along with a number of cam functions that can reduce the level of vibration. Polydyne and splinedyne cams are defined and methods for their calculation described.

Calculations for the cam contour of radial, barrel, and globoidal cams with oscillating or translating roller or flat followers are defined. Cutter compensation algorithms and cam surface generation are defined for all common cam-follower configurations. Conjugate cam calculation is defined as well. Cam materials and manufacturing techniques are described and recommendations made.

Stress analysis of the cam-follower joint is presented in detail along with methods to determine the failure modes of typical cam/follower materials in surface contact under time-varying loads. Lubrication and wear of the cam and follower is also addressed.

Methods for the experimental measurement of acceleration, velocity and displacement of cam-follower systems are described, and examples of such measurements taken on operating machinery are shown. Case studies from automotive and automated manufacturing machinery are presented.

The third edition adds treatment of cam- and servo-driven mechanisms based on research and work done by the author and his graduate students and colleagues in industry since the second edition appeared.

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Every effort has been made to ensure that the material in this book is technically correct. All known errors in earlier editions have been corrected in this edition. If errors remain, the author takes full responsibility, and will greatly appreciate their being pointed out to him. Please send an email to norton@wpi.edu if you discover any errors in the text or programs. Information on book errata as discovered, and demonstration versions of the computer programs mentioned throughout the text are downloadable from the author's website at http://www.designofmachinery.com. See Appendix A for more information.

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