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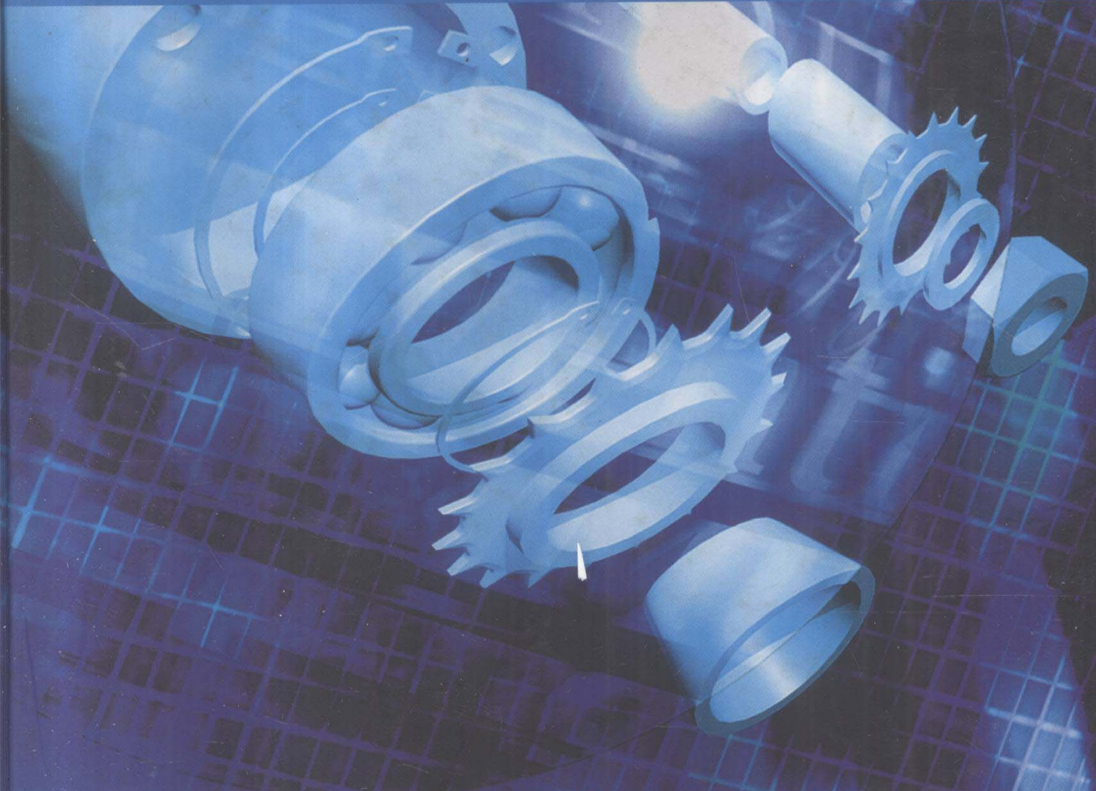

An Advanced Treatise on Fixture Design and Planning

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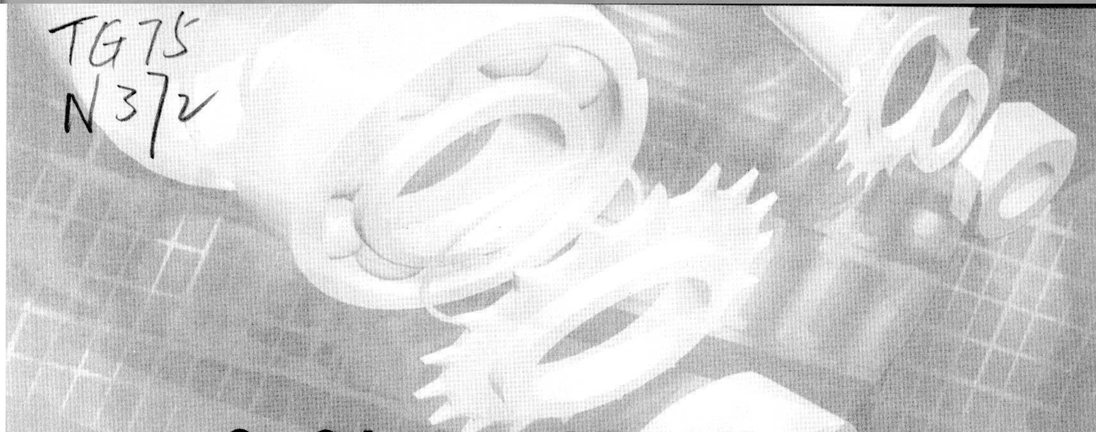

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Vol. 1: An Advanced Treatise on Fixture Design and Planning
Andrew Y. C. Nee, Z. J. Tao & A. Senthil Kumar

A.Y.C. Nee	To my wife Siew Kheng and daughters Joanne, Julianne, Suzanne for their patience and understanding
Z.J. Tao	To my wife Hongbing for her patience and support
A. Senthil kumar	To my parents Prof Anantharajan and Ms Vijayalakshmi, and my wife Amutha and son Saravan for their help and understanding

Preface

The primary goal of this book is to cover, as much as possible, the state-of-the-art development in the domain of computer-aided fixture design and planning. The text concentrates on key issues central to the development of computer-integrated manufacturing, such as fixture design automation, fixture clamping layout synthesis, clamping intensity optimisation, workpiece-fixture interaction, intelligent fixtures which are integrated with processing equipment or machine tools, Internet-enabled fixture design and modular fixture database management.

This book is intended to be a reference text for academics, manufacturing and industrial engineers. It may also be used as a text for engineering graduate students in the discipline.

The organisation of the book is arranged in a topical manner. It begins with a concise presentation of the generic principles of fixture design in Chapter 1. Chapter 2 discusses the concept of integrated computer-aided fixture design system. It presents a 3D CAD-based system which is able to produce automated, interference-free fixture design and assembly solutions. Chapters 3 and 4 cover the framework and methodology to determine a viable clamping layout in terms of optimal clamping points, positive clamping actuation sequence, and minimal sustainable clamping intensities.

The dynamic interaction between a workpiece and its fixture plays a crucial role in fashioning the finished accuracy of a part. Experimental investigation presented in Chapter 5 provides an insight into the workpiece stability and the inherent dynamic nature of the workpiece-fixture system. The book then details the architecture of an intelligent fixturing system in Chapter 6, which is capable of tool path compensation and on-the-fly moderation of fixturing parameters so as to minimize workpiece displacement and distortion.

Chapter 7 presents a fixture element database management system which is essential to the automation of fixture design process. It is followed by a description of an Internet-based interactive fixture design system in Chapter 8. This system promotes the concept of collaborative design in a distributed manufacturing environment.

Acknowledgements

During the period of preparing for the book, we have received excellent support from our colleagues. We would like to acknowledge the valuable contributions by Dr J.Y.H. Fuh, Dr M.A. Mannan and Dr Y.S. Wong at the National University of Singapore. Our graduate students have also contributed to this book with their research work, particularly: S. Senthilkumar, J.R. Dai, L. Lin, X.W. Gui, J. P. Sollie, Y.F. Wang, T.K. Xiao and Long Qin, and in specific chapters: Chapter 2 – T.S. Kow; Chapter 7 – Y.M. Yip; and Chapter 8 – S.H Bok, Ratnapu Kiran Kumar, Sandeep Kumar Arya, Y.J. Ng and Fathianathan Mervyn. We would also like to thank K.W. Tjan at World Scientific for his support in the production of this book.

Last but not least, we would like to dedicate the book to three distinguished academicians who have contributed indirectly to this book, they are the late

Dr Ken Whybrew
Professor Amitabha Bhattacharyya
Professor Inyong Ham

Dr Ken Whybrew was the co-author of a first book "Advanced Fixture Design for FMS" written together with AYCN and ASK. Prof Bhattacharyya provided an unpublished manuscript written with Prof Ham to AYCN many years ago and some materials of this manuscript are presented in Chapter 1.

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Table of Contents

Chapter 3 Fixture Clamping Layout Synthesis

Chapter 4 Optimisation of Dynamic Clamping Forces for a Fixture

Chapter 5 Workpiece-Fixture Interaction

Chapter 8 An Internet-Enabled Smart Interactive Fixture Design System

Chapter 1

Introduction to Fixture Design

1.1 Introduction

A fixture is a device for locating, holding and supporting a workpiece during a manufacturing operation. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations.

Fixtures must correctly locate a workpiece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the workpiece in that location for the particular processing operation.

There are many standard workholding devices such as jaw chucks, machine vises, drill chucks, collets, etc. which are widely used in workshops and are usually kept in stock for general applications.

Fixtures are normally designed for a definite operation to process a specific workpiece and are designed and manufactured individually. Jigs are similar to fixtures, but they not only locate and hold the part but also guide the cutting tools in drilling and boring operations. These workholding devices are collectively known as *jigs and fixtures*. Figure 1.1 shows an example of a fixture commonly used on a horizontal CNC milling machine.

1.1.1 Elements of Fixtures

Generally, all fixtures consist of the following elements:

- Locators

A locator is usually a fixed component of a fixture. It is used to establish and maintain the position of a part in the fixture by constraining the movement of the part. For workpieces of greater variability in shapes and surface conditions, a locator can also be adjustable.

- Clamps

A clamp is a force-actuating mechanism of a fixture. The forces exerted by the clamps hold a part securely in the fixture against all other external forces.

- Supports

A support is a fixed or adjustable element of a fixture. When severe part displacement/deflection is expected under the action of imposed clamping and processing forces, supports are added and placed below the workpiece so as to prevent or constrain deformation. Supports in excess of what is required for the determination of the location of the part should be compatible with the locators and clamps.

- Fixture Body

Fixture body, or tool body, is the major structural element of a fixture. It maintains the spatial relationship between the fixturing elements mentioned above, *viz.*, locators, clamps, supports, and the machine tool on which the part is to be processed.

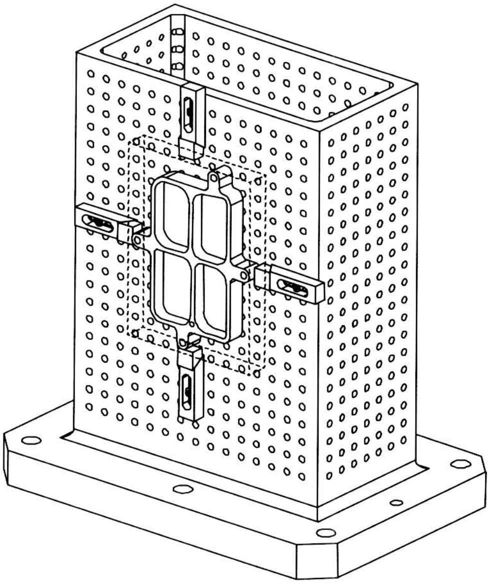

Figure 1.1 A typical 'tombstone' fixture for a horizontal CNC machine

1.1.2 Importance of Fixtures in Manufacturing

Modern manufacturing aims at achieving high productivity to reduce unit cost. This necessitates workholding devices to be efficient, *i.e.* to increase the rate of loading and unloading to speed up the manufacturing cycle time.

If t is the total time in seconds or minutes required for producing a part, then $Q = \frac{1}{t}$ is the number of pieces produced in unit time, or the production rate.

Considering the fact that the total manufacturing time is usually composed of:

$$t = t_m + t_h$$

where t_m is the actual machining time and t_h is the setting up and handling time, hence, the production rate is given by:

$$Q = \frac{1}{t_m + t_h} \text{ piece per unit time} \tag{1.1}$$

Supposing Q_t is the ideal production rate whereby there is no handling time loss for a given machining operation, hence we have:

$$Q_t = \frac{1}{t_m}$$

Now,

$$Q = \frac{1}{\frac{1}{Q_t} + t_h} = \frac{1}{1 + \left(\frac{t_h}{t_m}\right)} Q_t = \lambda Q_t \tag{1.2}$$

This factor $\lambda = \frac{1}{1 + \left(\frac{t_h}{t_m}\right)}$ can be termed as production efficiency.

The variation of λ with respect to Q_t is shown in Figure 1.2 for the various values of t_h. For an operation with a value of $t_m = t_h$, λ is 0.5 whereas, if $t_h = 2\, t_m$, λ is 0.33 and the production rate is reduced. Figure 1.3 shows how t_m and t_h affect production rate. It is clear from Figures 1.2 and 1.3 that

(a) For a given t_m, reduction of t_h increases Q,
(b) For a given t_h, reduction of t_m enhances Q.